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TRANSACTIONS

OF THE

GEOLOGICAL SOCIETY OF GLASGOW.

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OF GLASGOW.

VOL. IX.

1888-92.

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JAMES BARCLAY MURDOCH, F.R.Ph.S.E.

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No. I.—On the Fructification and Internal Structure of Carboniferous Ferns in their Relation to those of Existing Genera, with Special Reference to British Palæozoic Species. With Four Plates [Nos. I. to IV.]

By Robert Kidston, F.R.S.E., F.G.S.

[Read 14th March, 1889.]

I have great pleasure in acceding to the request of your Secretary to bring this paper before the members of the Geological Society of Glasgow, especially as immediately surrounding this city are large coal-fields, rich in the remains of the extinct flora which is to engage our attention for a short time this evening.

This paper has been suggested to me from a question often asked by beginners in the study of Palæozoic Botany, "In what book can I find the descriptions of British species?" Unfortunately this question cannot be answered, as no complete work on the British palæozoic flora has yet been published, and what has been written on the subject is, with few exceptions, scattered through the *Transactions* of various Societies which are frequently inaccessible to students of fossil botany, except to those in some of our large centres of population. But let us suppose that the beginner has access to all papers hitherto published on British palæozoic botany, none the less will he soon meet with species which, if previously recorded from Britain, are certainly not described in any English work. One therefore must make their identifications in great part from the writings of foreign authors.

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These volumes are expensive, and as very few of our libraries contain even some of the standard works on the subject, fossil botany in Scotland, and I might even say in Britain generally, has been but little studied. There are many intelligent collectors of fossil plants, but till there is a text-book on the subject in our own language, to the majority of them palæozoic botany must remain a closed but interesting chapter in one of the most inviting fields of natural history. It is therefore with the view of assisting our younger fossil plant collectors that the present paper has been prepared. It deals chiefly with those points of Carboniferous Fern Structure and Fructification which are sufficiently well known to enable a comparison to be made between past and recent genera, and this is done as briefly as possible. References to the original works are fully given, as half the battle is to know where to look for the description we wish, and the original works should in all cases be consulted.

As an appendix to this communication, I have given a list of the chief works and papers dealing with the fructification and structure of palæozoic ferns.

When studied with the object of discovering the affinities of extinct forms with those of existing genera, there is no more interesting branch of natural history than that of palæontology. It is true that the earlier workers in fossil remains did not always proceed on this line, and those possessed with the accumulated knowledge of generations are sometimes too ready to speak of the earlier workers in an uncharitable and often very unjust manner, forgetting that, of all branches of science, palæontology is that which depends more than almost any other on patient collecting and study. It is quite the exception to find a specimen showing the complete structure of the organism; its life-history and organisation have therefore to be made out, bit by bit, and pieced together from specimens often brought from the four quarters of the globe.

The original workers in palæontology, to whom all credit will be given by the true student, possibly did not appreciate the full importance of their investigations, nor with their limited knowledge of the subject could they see the important place it would occupy in the future.

The great discovery made by William Smith in the beginning of this century, that fossils, when treated with due caution, serve

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as indices for the correlation of strata which may be widely separated in space, seems to have prevented the earlier geologists from seeing in the study of fossils the still more engrossing field of work in investigating and elucidating the relationships and affinities which exist between recent and extinct genera and species.

When it is remembered that each *formation* was at one time supposed to represent a *special creation*—and in the earlier days of geology this was the view almost universally held—it was probably thought that any close affinity between fossil and existing forms could not exist.

SECTION I.

FERN STRUCTURE OF EXISTING SPECIES.

Before attempting to understand fossil organisms we must first acquaint ourselves with the structure and classification of those existing forms to which the fossils we desire to examine are most closely related. Unless this plan is adopted the study of fossils cannot be attended with much practical good.

This principle cannot be too strongly enforced on those who are beginning the study of palæontology, for most of the errors and misinterpretations of fossil remains, which form a blot on much palæontological work, have arisen from the neglect of this precaution alone.

In my remarks on the structure and classification of recent ferns I shall be as brief as possible, and I shall only enter on those points which are necessary for an intelligent appreciation of the points of agreement and difference between recent and fossil genera and species.

FILICACEÆ.

Ferns are classified in accordance with the manner in which the *sporangia* are developed. Looked at from this structural point ferns fall naturally into two divisions:—

A. LEPTOSPORANGIATE FILICACEÆ.

Ferns in the more restricted sense of the word; sporangia formed from a single epidermal cell, and provided with an *annulus*.

This division is further separable into—

I. HOMOSPOROUS FILICACEÆ.

II. HETEROSPOROUS FILICACEÆ.

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I. Homosporous Filicaceæ.

Here, as the name implies, the spores are of one kind. The ferns in this group may have more or less developed upright undivided stems, or the stems may be decumbent and divided. The fronds are extipulate, circinately rolled up when young, and bear sporangia which are usually developed on some part of the veins at the back of the frond, but may be developed from the mesophyll or ground tissue of the frond. The sporangia are rarely borne on both sides of the frond *(Olfersia)*. They may be sessile or stalked, and usually form groups termed *sori*, which are naked, or covered with a scale-like structure called an *indusium*. The part of the vein which bears the *sorus* is often thickened and more or less elevated, and so forms a *receptacle* or *placenta*.

The sporangia of this division of ferns are small roundish capsules, with a stalk in the Polypodiaceæ and Cyatheaceæ, but generally sessile in the others. The wall of the mature capsule is formed of one layer of cells, and a row of cells in this layer is developed in a peculiar manner and forms the *annulus*. (Plate I., figs. 1-6.) The annulus may take a transverse or oblique course across the sporangium, or form an upright band.

Sometimes the annulus is developed as a lateral group of cells, or forms an apical cap. The cells of the annulus are usually prominent and conspicuous.

The contraction of this structure at maturity, caused by the drying of the sporangium, bursts the capsule at right angles to the plane of the annulus.*

The position and structure of the annulus form an important character in the classification of the *Leptosporangiate* ferns.

The Homosporous Filicaceæ contain six families:—

Family 1.—Hymenophyllaceæ. (Plate I., fig. 1.)

The sporangia have an oblong or transverse complete annulus, and open by a longitudinal fissure. They are borne on a prolongation of the fertile vein,—the columella or placenta, which projects beyond the margin of the leaf, and is surrounded by a cup-shaped indusium. Sporangia sessile except in *Loxsoma*, where they are stalked.

* The bursting of the sporangia is accompanied by a little jerk, which assists in the dissemination of the spores.

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Family 2.—CYATHEACEÆ. (Plate I., fig. 2.)

The sporangia have a short stalk and a complete oblique eccentric annulus. They are placed on a placenta, which is often greatly developed, and form a sorus which is usually closely packed, and is either naked or surrounded by a cup-shaped indusium which sometimes forms a closed capsule.

Family 3.—POLYPODIACEÆ. (Plate I., fig. 3.)

Sporangia with a vertical incomplete annulus; numerous, placed on the veins or on the mesophyll on the under side of the usually unaltered fronds, rarely on both surfaces of the frond (*Acrostichea*), naked or indusiate.

Family 4.—GLEICHENIACEÆ. (Plate I., fig. 5.)

Sporangia sessile, usually 3-4 in a sorus on the dorsal surface of the ordinary leaves; annulus transverse and complete.

Family 5.—OSMUNDACEÆ. (Plate I., fig. 4.)

Sporangia arranged in panicles and placed on the laciniæ of leaves that have no mesophyll (*Osmunda*) or the fertile leaves resemble the sterile (*Todea*). Sporangia of unsymmetrical roundish form on short stalks; annulus on one side near the apex and composed of a group of peculiarly formed cells.

Family 6.—SCHIZÆACEÆ. (Plate I., fig. 6.)

The laciniæ that bear the sporangia arranged in spikes or panicles, or on the under surface of the frond near the margin, which is turned back over them; sporangia ovoid or pear shaped; annulus composed of peculiarly formed cells surmounting the sporangium like a cap.*

II. HETEROSPOROUS FILICACEÆ, OR HYDROPTERIDEÆ.

This latter division includes the Salvinaceæ and Marsilaceæ, in whose sporangia are contained macro- and microspores, but as it is not my intention to consider the fossil allies of these plants this evening, we shall not enter into their structural peculiarities.†

* It is almost unnecessary to mention the names of the works containing fern classification, as it is given in all the better text-books, but the two following may be specially noted:—"Outlines of Classification and Special Morphology," Goebel; and "Comparative Anatomy of the Phanerogams and Ferns," De Bary. (English editions.)

† Dawson, "On Rhizocarps in the Erian (Devonian) Period in America." *Bull. Chicago Acad. of Science*, vol. i., no. 9, 1886, p. 105.

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B. EUSPORANGIATE FILICACEÆ.

In these ferns the sporangia proceed from a group of cells. The species are all *homosporous*, and the sporangia *exannulate*. As a number of the Carboniferous species, of which the fruit is known, belong to this group of ferns—a group which is but feebly represented in recent times when compared with their palæozoic ancestors—it is necessary that the fructification of the recent genera be carefully considered.

This division contains two orders :—

I. MARATTIACEÆ, and II. OPHIOGLOSSACEÆ.

Order I.—MARATTIACEÆ comprises the five following genera :—

a. Marattia, Sm.
b. Eupodium, Sm.
c. Angiopteris, Hoffm.
d. Danæa, Sm.
e. Kaulfussia, Blume.

a. Marattia, Sm. (Plate I., fig. 7.)—Synangia* sessile, superficial, oblong, distant, sub-terminal, longitudinally bivalved, each valve consisting of 3-12 laterally connate thick-walled sporangia. The sporangia are narrow-cordate, acute, and open by a slit on their inner side.

In the earlier stages of development the two inner sides of the valves of the synangium are adpressed face to face, but towards maturity the valves separate and bend backwards and outwards. The fronds are from 6-18 feet long.

b. Eupodium, Sm.—The synangia are similarly formed to those of *Marattia*, but are pedicellate.

c. Angiopteris, Hoffm. (Plate I., fig. 8.)—Receptacles oblong, linear, obovate retuse; sporangia biserial, thick-walled, sessile, free, contiguous, opening by a slit on the inner side; sori oblong, latterally contiguous, forming a broad sub-marginal transverse band.

d. Danæa, Sm. (Plate I., fig. 9.)—Synangia sessile, immersed, linear, contiguous, occupying nearly the whole length of the venules and covering the whole under surface of the fertile fronds; each synangium consists of two rows of numerous laterally and oppositely connate obliquely oval sporangia, forming a concrete mass; each sporangium opens by an apical circular pore. Fronds 1-3 feet long.

* When the sporangia are united to each other, the term *synangium* is applied to the structure.

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e. Kaulfussia, Blume. (Plate I., fig. 10.)—Synangia sessile, superficial, orbicular, concave-hemispherical, each consisting of 10-20 clavate sporangia laterally connate in a circular series and opening by a slit on their inner side.

In the Marattiaceæ the sporangia are formed of several layers of cells and the base of the frond bears two lateral fleshy stipulæform appendages, with the exception perhaps of some species of *Danæa*.

Order II.—Ophioglossaceæ. This order contains three genera:—

a. Ophioglossum, Linn.
b. Helminthostachys, Kaulf.
c. Botrychium, Linn.

a. Ophioglossum, Linn.—Fructification in a distichous spike, terminating a distinct branch of the frond, or on a distinct frond. The sporangia form cavities in the tissue of the fertile portion of the frond and on its lateral faces, but somewhat nearer to one margin. Dehiscience by a transverse slit.

b. Helminthostachys, Kaulf.—Fructifications consisting of glomerate verticillate tufts of sporangia, the whorls terminated by a crest-like appendage and arranged in distichous spiked panicles on a distinct branch of the frond. Sporangia fleshy, coriaceous, globose, sessile, inverse, bursting on the outer side from the base upwards into equal or sub-equal hemispherical valves.

c. Botrychium, Linn.—Fructifications paniculate, formed of numerous secund spikelets on a distinct branch of the frond, sporangia erect, sessile, free, biserial, fleshy, coriaceous, bursting vertically into two equal hemispherical valves.

As none of the fossil fructifications which I wish to bring before you have any close affinities with the Ophioglossaceæ, this order may be passed over for the present.

Development and Arrangement of the Parts of the Frond.

The fern frond may be simple, as is the common Hart's tongue *(Scolopendrium vulgare)*, or variously divided. Among these latter a pinnate arrangement is perhaps the most prevalent. Here the frond appears as if it possessed a continuous growing axis, from which are given off in one plane opposite or alternate branches *(pinnæ)*. Such an appearance is, however, entirely deceptive, as the fronds of ferns divide by a series of dichotomies, but one of the forks of each dichotomy is usually arrested in its development.

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First let us examine a case of simple dichotomy. Here the growing point divides into two equal arms; each of these arms again divides and produces branches of the second degree. This process is repeated till there is produced a very complex series of ramifications of different degrees, each succeeding series or generation containing twice as many branches as that which preceded it. This form of ramification is characteristic of the *vascular cryptogams*, and is well seen in *Lycopodium* and *Selaginella* among recent genera, and in the fossil genera *Lepidodendron* and *Bothrodendron.*

Now let us suppose that the further development of one of the two arms of each dichotomy is arrested and repeats no further dichotomies, but that the other arm divides again. Let one of the arms of this last fork dichotomise, but let the further development of the other corresponding arm be suppressed, and if the forks in which further development has been arrested be situated alternately to the right and left of the axis, they are thrown aside by the stronger growth of their corresponding arms which have continued to dichotomise. Thus results the apparently pinnate arrangement of the pinnæ on fern fronds, and though they possess all the appearance as if the pinnæ were developed laterally from a continuous axis, the axis of a fern frond is in reality compound, and its component parts belong to different and successive dichotomies—the various portions of the axis representing in fact the arms of the dichotomies which have further divided. Such is the explanation of the ramification of most fern fronds.*

There is another form of sympodial ramification which occurs in ferns, being produced when the non-developed arms of the dichotomy are all placed on one side of the rachis. This results in the rachis being more or less curved or bent, and has been distinguished as *bostrychoid* dichotomy. This form of *sympodial* dichotomy occurs in *Adiantum pedatum.*

An equal dichotomy takes place in the fronds of a few ferns, such as *Actiniopteris radiata* and *Rhipidopteris peltata*, but by far the commonest form is that which produces the pinnate appearance and has been named *cicinnal* dichotomy.

There is still one point to which I would like to call your attention before leaving this subject.

* Called cicinnal dichotomy.

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The growth of the fern frond is strictly *basifugal* or *apical*, in consequence of which the lower pinnæ may be fully developed while the apex of the frond still continues to produce new pinnæ. In some species, after the first pair of pinnæ are developed, the further growth of the frond comes to a standstill, and the apex of the frond remains as a bud between the forks of the two pinnæ. At a subsequent period the bud may continue its development, but frequently it proceeds no further, as in many *Gleichenia* and *Mertensia*, where the fronds appear as if formed from a series of true dichotomies; but here again there is merely an example of cicinnal dichotomy simulating true dichotomy, which is brought about by the arrested development of the growing point.*

From the bud in the forks of the pinnæ of *Mertensia* there may be produced a few irregular frondose growths as in *M. (Gleichenia) gigantea*, Wall.†

Forked or tasselled varieties of ferns, usually the result of cultivation, are formed by a series of equal dichotomies of the growing points of the pinnæ or apex of the frond.

Let the ramification of Carboniferous fern fronds now be looked at, and as the structural points of those of recent ferns have been so fully considered, it may be done very shortly. One point that cannot fail to strike the botanist in regard to this is the much more common occurrence of equal dichotomy. The fossil specimens usually met with do not show this, for even the larger and more perfect examples generally represent only one arm of the dichotomy. Among the Sphenopteroids a dichotomous ramification is frequent, either of the main rachis or of the secondary rachis. I should perhaps say here that the genus *Sphenopteris*, as constituted and employed by Brongniart and subsequent writers till within the last few years, comprised ferns evidently belonging to many different genera; but from the absence of any knowledge of their fruit, it seemed advisable to make its generic characters very wide, as it is all but impossible to found satisfactory and restricted genera from characters derived from the nervation alone. It must therefore be regarded rather as a group

* Several of the figures of *Gleichenia* in Hooker's "Species Filicum," vol. i., show this. Many species of the genus are in cultivation, and can be easily studied.

† Hooker, "Species Filicum," vol. i., plate iiiA.

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than as a true genus. Of many of these Sphenopteroids the fructification has been discovered, and as this character becomes known new genera founded upon the fructification are formed for the reception of these fruiting species.

In some of the species of *Calymmatotheca (Sphenopteris)* the main rachis apparently forms a true dichotomy, each limb of which bears the alternate lateral pinnæ. In certain other species the main rachis gives off naked alternate secondary raches which bifurcate, and on the bifurcations are the foliage-bearing pinnæ. Dr. Stur * has formed the genus *Diplothmema* for these Sphenopteroids. In another group of ferns, some of which were formerly placed in *Sphenopteris* and others in *Pecopteris*, the main rachis bears alternate naked secondary raches which bifurcate in an open angle and each of the resulting arms again bifurcate, and on these latter are borne the foliage-bearing pinnæ. Zeiller has applied the name of *Mariopteris* to these ferns.† Both *Diplothmema* and *Mariopteris* contain many British species. As an example of the former *Sphenopteris furcata* may be mentioned, and of the latter *Pecopteris muricata*.

These two genera are not altogether satisfactory, for their fructification is unknown. In regard to *Diplothmema*, it is founded on an *additional* character to those formerly known to occur in *Sphenopteris*, and the genus is therefore, according to my view, utterly untenable. With respect to *Mariopteris* for one of the species included in it, *M. muricata*, although its fruit is unknown, the genus is desirable, for the nature of the plant and the texture of the pinnules separate it at sight from all other species, but for all or most of the other members of the genus I think they should be retained in *Sphenopteris*.

A dichotomous ramification of the pinnæ (apparently brought about by the arrested development of the growing point), and the fructification of *Pecopteris Pluckenetii*, Sternb., have been described by Sterzel,‡ who has proposed for this fern the generic name of *Dicksoniites*.

The presence of an undeveloped bud between the forks of the pinnæ of *Gleichenia* has been already referred to, and a similar undeveloped bud has been observed in a like position in *Dick-*

* Stur, "Die Culm Flora," heft ii., 1877, p. 233.

† Zeiller, *Bull. Soc. Géol. de France*, 3e sér., 1879, vol. vii., p. 92.

‡ Sterzel, *Botanisches Centralblatt*, no. 8/9, 1883, plate vi.

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soniites and *Sphenopteris (Diplothmema) subgeniculata*, Stur.* Both of these are British species.

In regard to generic characters derived from the bifurcation of the pinnæ, it may be mentioned that in *Gleichenia (Mertensia)* the pinnæ of the frond are sometimes formed of one, at other times of two pairs of forks.

The pinnæ of certain species of the common Carboniferous genus *Neuropteris* appear to have dichotomised several times.

In recent ferns, in addition to the rachis frequently bearing scales, the upper and lower surfaces of the pinnules also occasionally bear hairs or scales, as in *Ceterach officinarum*. Among fossil species the same structures are found. The rachis of many palæozoic species has been more or less densely covered with scales, and in many species of *Pecopteris*, of the *P. arborescens* group, the upper surface of the pinnules is covered with a dense clothing of hair which imparts a velvety appearance to it. So dense is this covering in some cases that it entirely obscures the veins.

In *Neuropteris Scheuchzeri*, Hoffm., *N. horrida*, Zeiller, and some other members of the genus, the upper surface of the pinnules also bears hairs. On some Sphenopteroids the same character is seen.

Arrangement of Veins and Pinnules.

The veins in the pinnules of both recent and palæozoic ferns are most diversified in their arrangement—the chief modes of arrangement occurring alike in both.

The veins may radiate fan-like from the base of the pinnule, or a main vein may give off lateral simple, or more or less dichotomised veinlets, or the veinlets may anastomise and form a network *(Dictyopteris* and *Lonchopteris)*. The pinnules are stalked, or united by their whole base to the rachis, and may further be united among themselves to a greater or lesser extent, and decurrent on the rachis, which in turn may be winged. As one or more of these different forms of nervation may occur among recent ferns in one and the same genus, the character of the nervation alone is of little value for a satisfactory generic distinction. A slight examination of recent genera will show how the nervation varies in certain genera, and, further, how it varies on different parts of the same frond.

* Stur, "Culm Flora," p. 241, plate xxix., fig. 8.

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Notwithstanding this, by far the greater number of palæozoic ferns are classified from characters derived from the nervation, coupled, however, with the form of the pinnules and their mode of attachment to the rachis. From this it will be seen that much of this classification is provisional; but, while recognising the great disadvantage under which the palæo-botanist works, experience has shown that many of the fossil genera founded on the characters just mentioned are so well characterised, that probably, in some cases at least, they form natural groups. The venation, however, forms undoubtedly one of the best characters for discriminating fossil species, but it requires a little experience to distinguish real differences, for the nervation of the pinnules, situated towards the apex of the pinnæ, is generally slightly different in detail from that of the pinnules placed towards their base.

To sum up this part of our comparison of Carboniferous with recent ferns, it will be seen, in regard to the ramification of the frond, that the same laws which regulate the development of the fronds of existing species also controlled the growth of those of Carboniferous times, though dichotomous ramification of the frond appears to have been much more frequent in palæozoic times than at present.

In some cases the apparently equal dichotomy in palæozoic species *may* have arisen from an arrested development of the growing point, as in *Gleichenia* and *Mertensia*, whilst at other times it seems to be a case of true equal dichotomy.

Aphlebia.

On certain recent ferns, as at the base of the rachis of *Alsophila (Hemitelia) capensis*, J. Sm., there are developed what may be called abortive pinnæ, about 3-4 inches long, many times multifid, with narrow linear membranous segments and a rigid costa. These at first sight resemble a *Trichomanes* or *Hymenophyllum* in a barren state, growing parasitically on the *Alsophila*, and Kaulfuss has described these abortive pinnæ under the name of *Trichomanes* (?) *cormophyllum*. (Hooker. "Species Filicum," vol. i., p. 37.) Also in *Gleichenia gigantea*, Wall., a collection of leafy, deeply laciniate persistent scales arises at the base of the primary pinnæ.

Among fossil ferns the development of similar Aphlebia are of

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even more frequent occurrence, and though many of these so-called Aphlebia have been found attached to fronds and are undoubtedly an integral part of them, there are other allied fossils of large size, regarding which I am not quite sure that they do not form individual species. Of such is the *Rhacophyllum (Schizopteris) lactuca*, Sternb., sp., and allied forms.

With those Aphlebia, however, which must be classed as an integral part of the frond on which they occur, *Schizopteris adnascens*, L. and H.,* must be included. This was originally supposed to be a distinct species of climbing fern which had twined up the rachis of *Sphenopteris crenata*, L. and H.

SECTION II.

DESCRIPTIONS OF THE FRUCTIFICATION OF CARBONIFEROUS FERNS.

A. SPORANGIA PROVIDED WITH AN ANNULUS.

Isolated *annulate sporangia* are not of uncommon occurrence at those localities in Britain which yield fossil plants with their internal structure preserved, as at Pettycur, Fife (Calciferous Sandstone series), and the Yorkshire and Lancashire coal fields. (Plate I., figs. 11, 12, 13.)

In all structural points many of these sporangia are individually identical with those of recent annulate sporangia, in their wall being composed of a single layer of cells, certain of these being enlarged to form the annulus; but in all cases where the sporangia have been found in position on the fronds, the position of the annulus and the arrangement of the sporangia are apparently different from that of the sporangia of any existing genus.

HYMENOPHYLLITES, Göppert, 1836.

(Plate I., fig. 14.)

Hymenophyllites, Göppert, "Syst. Fil. Foss.", p. 251.
,, Zeiller, *Ann. d. Sci. Nat.*, 6e sér., Bot., vol. xvi., p. 195.
,, ,, "Flore foss. d. bas. houil. d. Valen.", p. 56, fig. 36. (*H. quadridactylites*, Gutbier, sp.)

Description.—Fructification resembling that of *Hymenophyllum;* sporangia pyriform, pointed at the base, provided with a complete transverse annulus and placed at the extremities of the lobes of the pinnules.

* Lindley and Hutton, "Fossil Flora," vol. ii., plate c., ci.

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Remarks.—The actual presence of a column to which the sporangia were attached has not yet been observed, but the manner in which the sporangia are placed on the specimen of *Hymenophyllites quadridactylites*, Gutb., sp., figured by Zeiller,* points very strongly in favour of the view that the sporangia had originally been attached to a column, for they are occasionally arranged in two slightly irregular parallel rows, continued outwards from the extremity of the pinnule, and having between them a clear space which looks as if it had originally been occupied by some structure that has now disappeared. Although the species included in *Hymenophyllites* cannot, from what we know of their fructification, at present be referred to the genus *Hymenophyllum*, there is still sufficient evidence to show that during Upper Carboniferous times, there existed a *genus* of ferns closely related to *Hymenophyllum*, and though it cannot be said with certainty that these ferns belong to any existing genus, they can however be placed in the Hymenophyllaceæ.

The only claim Britain has to *Hymenophyllites*, as far as I am aware, is founded on the occurrence of a small barren specimen of *Hymenophyllites quadridactylites*, Gutb., sp., from the "Ten-feet Ironstone Measures," Coseley, near Dudley (Middle Coal Measures), which has lately been submitted to me for examination by Mr. Herbert W. Hughes, F.G.S.†

Oligocarpia, Göppert, 1841.

(Plate I., fig. 15.)

Oligocarpia, Göppert, "Gatt. d. Foss. Pflanzen," lief. 1 and 2, p. 3, plate iv., figs. 1 and 2 (*O. Gutbieri.*)

,, Zeiller, *Ann. d. Sci. Nat.*, 6e sér., Bot., vol. xvi., p. 190, plate x., figs. 6-15.

,, Zeiller, "Flore foss. d. bas. houil. d. Valen.", p. 53, fig. 35.

,, Schimper, "Traité d. Paléont. Végét.", vol. i., p. 585, plate xli., figs. 8-9.

Renault, "Cours d. Botan. Foss.", 3e an. (1883), p. 67, plate vii., figs. 1 and 3.

* *Loc. cit.*, *Ann. d. Sci. Nat.*, and "Flore foss. d. bas. houil. d. Valen."

† In studying the Carboniferous Hymenophyllaceæ we must dismiss from our minds the *Hymenophyllum Weissii*, Schimper ("Traité d. Paléont. Végét.", vol. i., p. 246, plate xxviii., figs. 4-7), from the Coal Measures of Saarbrück, for according to Solms-Laubach the figures and description of this fossil are inaccurate. (Einleitung in die Paläophytologie vom botanischen standpunkt, 1887, p. 157.)

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Description.—Sporangia pyriform, in number from 3-10 attached by their narrow extremities to the summit of the fertile veins, and placed on the limb in a "rose-like" heap, thus forming a circular, or sometimes hemispherical sorus, in which case some of the sporangia in the centre of the group stand erect. The sporangia are provided with a complete transverse annulus formed of one row of cells.

Remarks.—When the sporangia are viewed laterally, the position in which those which occupy the lowest and outermost circle of the sorus are seen admits of the annulus only being seen on their external face, its continuation being hidden beneath; but when the sporangia are viewed from above, as those in the centre of the sorus may be, the annulus is seen to form a complete circle.

The structure of the fruit of the *Oligocarpia* presents therefore a complete identity, as well in the structure of the individual sporangia as in their arrangement into sori, with that of *Gleichenia*. It is true that the ramification of the fronds of *Oligocarpia* and *Gleichenia* differ much. In the former the regular pinnate fronds do not show any similarity to the dichotomously-like divided fronds of *Gleichenia* (through non-development of the growing point), but in the more important character of fructification *Oligocarpia* and *Gleichenia* possess sporangia so similar in structure and arrangement that there can remain no doubt as to the true position of *Oligocarpia* being in the Gleicheniaceæ.

The only species of the genus I have yet seen in Britain is *Oligocarpia Brongniarti*, Stur, which was collected by Mr. W. Hemingway in shale over the "Barnsley Thick Coal," at Woolley Colliery, Darton, near Barnsley. (Middle Coal Measures.)

SENFTENBERGIA, Corda, 1845.

(Plate II., fig. 16.)

Senftenbergia, Corda, "Beitr. z. Flora d. Vorwelt," p. 91, plate lvii., figs. 1-6.

,, Zeiller, "Flore foss. d. bas. houil. d. Valen.", p. 50, fig. 34 (*S. elegans*, Corda).

,, Zeiller, *Ann. d. Sci. Nat.*, 6e sér., Bot., vol. xvi., p. 188, plate x., figs. 1-5 (*S. elegans*, Corda).

,, Schimper, "Traité d. Paléont. Végét.", vol. i., p. 578, plate xli., figs. 4-7.

Description.—Sporangia ovoid, pointed at the summit, sessile, arranged in two parallel series, one on each side of the medial vein,

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provided with an apical conical cap-like annulus, which occupies about two-fifths of the height of the sporangia, and formed of many rows of thick-walled cellules: dehiscing by a longitudinal split, which is directed towards the margin of the pinnule.

Remarks.—A line of narrow cells extends, apparently from the apex to the base of the sporangium, at which part the sporangia burst at maturity. The dehiscence is brought about by the contraction of the apical annulus, as in the Schizæaceæ.

Though the position of the annulus in *Senftenbergia* is similar to that in the Schizæaceæ, in *Senftenbergia* it is composed of several rows of cells, whereas in the Schizæaceæ (of which the chief genera are *Schizæa*, *Aneimia*, *Lygodium* and *Mohria*), it is composed of a single row of cells which are much elongated vertically.

In the closely allied tribe Osmundaceæ, the annulus does not completely encircle the sporangia, but forms a patch composed of several rows of polygonal cells. *Senftenbergia* agrees, therefore, in the several "cell-rowed" structure of the annulus with the Osmundaceæ, but differs in the annulus forming a complete cap. With the Schizæaceæ it agrees in the annulus forming a *complete cap*, but differs in the cap being composed of several rows of cells. The difference, however, between the sporangia of *Senftenbergia* and those of Schizæaceæ is very slight, so slight that I believe *Senftenbergia* should be placed in the same tribe. I am not aware that *Senftenbergia* has yet been observed in Britain.

Corynepteris, Baily, 1860.

(Plate II., fig. 17.)

Corynepteris, Baily, "Explan. to sheet 142, Geol. Surv. Ireland," p. 16.
,, Baily, *Nat. Hist. Rev.*, vol. vii., p. 258, plate xiv.
,, Zeiller, "Flore foss. d. bas. houil. d. Valen.", p. 41, fig. 28.
Grand 'Eurya, Zeiller, *Ann. d. Sci. Nat.*, 6e sér., Bot., vol. xvi., p. 203.
Saccopteris, Stur, "Zur Morph. und Syst. d. Culm u. Carbon Farne," p. 64.
,, Stur, "Carbon Flora," vol. i., p. 159.
Grand 'Euryella, Weiss, *Neues Jahrb. fur Miner.*, 1885, vol. i., p. 492.

Description.—Fertile pinnæ similar to the sterile, or the limb of the pinnules more or less reduced; sporangia of large size, ovoid, sessile, provided with a complete longitudinal annulus formed of many rows of cells. Sporangia grouped to the number of from 5-10 around the same point, forming by their union a spheroidal

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sorus—the sporangia touching each other by the edges of their annuli which encompass their dorsal aspect.

Remarks.—The sori appear to be situated on the medial nerve towards the base of the fertile pinnule. Owing to differences in their preservation, the sori are sometimes flattened, and the component sporangia appear triangular, and arranged star-like round a common point of attachment, the annulus forming rays diverging from the centre: sometimes the sori are flattened laterally and lie parallel with the pinnule, and the sporangia being close together the sorus looks like a small melon. Occasionally all these conditions are found on one and the same pinna. The annulus is formed of several rows of thick-walled cells which are broader than long, whilst those on the other parts of the sporangia are longer than broad and with thinner walls.

Towards the base of the sporangia the cells of the annulus become less and less differentiated from those of the walls, and finally assume the same aspect.

These sporangia in their general structure closely resemble those of *Zygopteris* (to be presently described), and might be easily mistaken for them.

In *Zygopteris*, however, the sporangia are clearly pedicellate, less regularly grouped, and generally do not touch each other by their annuli, and they never show in imprints a star-like grouping which is so often observed in *Corynepteris*, and, finally, in *Zygopteris* the fertile pinnules are entirely deprived of the limb.

Corynepteris and *Zygopteris* belong to a group whose fructification separates them altogether from any existing genera.

This genus was described by Baily from a specimen procured by Mr. G. H. Kinahan from the old collieries near Glin, in the townland of Ballygiltenan Lower, County Limerick. I have also met with the genus in the South Wales and English coalfields.

Renault includes *Zygopteris* and one or two allied genera in a group which he has named "Botryopterideæ." Recent investigation necessitates, however, a slight modification of the characters of this group as defined by him. ("Cours d. Botan. Foss.", 3e an., p. 100, 1883.)

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ZYGOPTERIS, Corda, 1845.

(Plate II., fig. 18.)

Zygopteris, Corda, "Beitr. z. Flora d. Vorwelt," p. 81.
,, Renault, *Compt. Rend. Acad. Sci.*, vol. lxxxii., p. 992.
,, ,, *Ann. d. Sci. Nat.*, 6e sér., Bot., vol. iii., p. 5.
,, Zeiller, "Flore foss. d. bas. houil. d. Valen.", p. 46, fig. 30 (*Z. pinnata*).

Description.—Fertile pinnules deprived of the limb; sporangia of large size, ovoid, much longer than broad, tapering into a pedicel at the base, and united from 5-15, or perhaps more, to the extremity of a common peduncle; sporangia often a little arched and provided with a complete longitudinal annulus formed of many rows of cells.

Remarks.—This genus was founded by Corda for fossil fern petioles or fragments of the rachis, having the vascular system in the form of a *double-anchor*, and Renault has been successful in finding some sporangia attached to a fern stem which possessed all the characters of the genus *Zygopteris* of Corda. These specimens described by Renault were preserved in silica and exhibited the minute structure of the sporangia. According to him the wall of the sporangium is formed of several rows of cells, in the interior of which is a very delicate membrane, contracted and separated from the external wall, and in this were contained numerous smooth spores. The wall of the sporangium being composed of more than one series of cells, and having in addition a very prominent and clearly differentiated compound annulus, shows that *Zygopteris* is distinctly separated from all recent genera of ferns. (Zeiller, *op. cit.*, p. 46.)

SCHIZOSTACHYS, Grand 'Eury, 1877.

(Plate II., fig. 19.)

Schizostachys, Grand 'Eury, "Flore Carbon. du Départ. de la Loire," p. 200.

Remarks.—This genus is probably identical with *Zygopteris*. It was characterised by Grand 'Eury as having oblong, slightly curved pedicellate sporangia, attached around a common point or on the sides of a common pedicel. The sporangia wall is thick and complex, and is composed of two layers—the external cellular, the inner fibrous.

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The British specimen I refer to this genus was collected at Radstock from the Radstock series of the Somerset and Bristol coal-field.*

The internal structure of the sporangia of my example is not preserved, it being merely an impression, but the outer surface of the oblong sporangia, which are usually developed in pairs on a bipinnate frond (?), shows a longitudinal line from which extend on each side fine transverse bars. This vertical series of transverse bars may, I think, be the annulus, but owing to the specimen not showing all the characters necessary for a satisfactory determination of the generic position of the fossil, its true position is somewhat doubtful. I have placed it, provisionally, in *Schizostachys*, under the name of *S. sphenopteroides*.

B. SPORANGIA EXANNULATE.

SCOLECOPTERIS, Zenker, 1837.

(Plate II., fig. 20.)

Scolecopteris, Zenker, *Linnæa*, vol. xi., p. 509.
,, Schimper, "Traité d. Paléont. Végét.", vol. i., p. 680.
,, Zeiller, "Flore foss. d. bas. houil. d. Valen.", p. 39, fig. 25.
Acitheca, Schimper, "Handb. d. Palæont.", vol. ii., p. 91.

Description.—Fertile and barren pinnules similar, or the limb of the fertile pinnules only slightly reduced, and the margin often rolled backwards. The sporangia taper at the summit to a sharp point, and are united to the number of 4-5 around a very prominent receptacle. Each group thus forms a pedicellate synangium normally standing erect from the limb.

Remarks.—This genus differs from *Asterotheca* (next to be described), in the sporangia ending in a long tapered point, and in the synangia being pedicellate. When found as impressions the synangia are usually flattened, giving the pinnules the appearance as if covered with stiff bristles.

According to the investigations of Renault ("Cours d. Botan. Foss.", vol. iii., p. 116, plate 20, figs. 7-10), the receptacle contained 4-5 prominent ridges, being in transverse section stellate, and to each ridge was attached the inner surface of one of the sporangia.

The wall of the sporangium is formed of several layers of thick-walled cells, except on the side by which they are attached to the receptacle, where the thick wall is not developed, and its place

* *Trans. Roy. Soc. Edin.*, vol. xxxiii., p. 352, plate xx., fig. 1.

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is taken by a thin partition of delicate cells. At maturity the sporangia open by a longitudinal slit which passes through the line of this delicate membrane.

The only species of *Scolecopteris* occurring in Britain is *S. polymorpha*, Brongt., sp., which is found in the Upper Coal Measures.

Asterotheca, Presl., 1845.

(Plate II., fig. 21.)

Asterotheca, Presl. in Corda, "Beitr. z. Flora d. Vorwelt," p. 89.
,, Zeiller, "Flore foss. d. bas. houil. d. Valen.", p. 36, figs. 23 and 24.
Asterocarpus, Göpp. (*not* Necker, Ecklow, nor Zeyher), "Syst. Fil. Foss.", p. 188.
Hawlea, Corda, "Beitr. z. Flora d. Vorwelt," p. 89, plate lvii., figs. 7 and 8.
Grand 'Eurya, Stur (*not* Zeiller), "Zur Morph. und Syst. d. Culm u. Carbon Farne," p. 45.
Scolecopteris, Stur (*in part*), ibid., p. 88.

Description.—Fertile pinnules similar to the barren or the limb, only little reduced; sporangia ovoid, acute or slightly obtuse at the summit, united to the number of 4-5, rarely more or less, around a very slightly elevated receptacle, each group thus constituting a sessile synangium, which in the normal condition stands erect.

Remarks.—The synangia are attached to the secondary veins, sometimes near the base, sometimes near their centre, more rarely at their extremity close to the margin of the pinnule.

The sporangia which constitute the synangia are usually equally developed, but in some species those sporangia of the group that form the side of the synangium next to the margin of the pinnule are more developed and larger than those next to the midrib of the pinnule. Most commonly each pinnule bears two parallel series of synangia—one on each side of the medial nerve. Sometimes, however, on large pinnules which are probably composed of smaller pinnules united by their margins, one sees on each side of the central vein two parallel series of synangia. This has been observed in *Pecopteris oreopteridia*, Schl., sp., and *P. Miltoni*, Artis, sp.

The receptacle around which the sporangia are attached appears to have been more or less elevated according to the species, without, however, attaining a height equal to that of the sporangia them-

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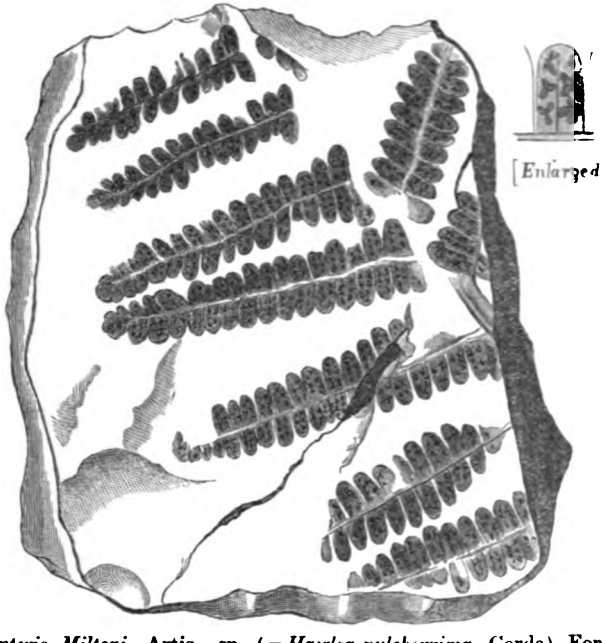
selves, which remain always free at the summit and without doubt throughout a great part of their height.

It would appear from the researches of Grand 'Eury* and Renault† that the sporangia at maturity open by a vertical longitudinal cleft.

In the earlier stages of the development of the synangia of *Asterotheca*, the sporangia are erect and closely adpressed against each other, but towards maturity they separate and become bent back on the limb of the pinnule, forming a star-like group.



Pecopteris Miltoni, Artis., sp. (=*Hawlea pulcherrima*, Corda), Forest of Wyre, Worcestershire. In the Collection of the British Museum.

A very similar sequence of developmental stages is seen in *Marattia*. At first the two rows of the oval synangia are closely adpressed to each other by their inner surfaces, but towards maturity the two rows begin to separate from each other, and at length those surfaces which originally pressed upon each other are eventually directed outwards and upwards in a line almost

* "Flore Carbon. du Départ. de la Loire," 1877.

† "Cours de Botan. Foss.", 3e an., Fougères, 1883.

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horizontal with the surface of the pinnule.* Dehiscence takes place here also through a longitudinal ventral cleft.

In *Marattia* the sporangia are laterally united throughout their whole length and form two opposite parallel rows, which are united at their extremities—thus forming an oval synangium. In *Asterotheca* the sporangia are only united at their base, are much fewer in number in each synangium, and are arranged in the form of a star.

Asterotheca has also affinities with *Kaulfussia*. In the latter the sporangia, by complete union round a common circular receptacle, form cup-like synangia. If then we imagine the sporangia separated from each other, except at their basal extremity, we should have an arrangement of synangia similar to that which occurs in *Asterotheca* at maturity.

Asterotheca differs chiefly from *Scolecopteris*, to which it is closely related, by its having short capsules, and in the synangia not being pedicellate, or only very slightly so.

All the members of the genus *Asterotheca* at present known belong to the genus *Pecopteris*, Brongt. They are characteristic of the Upper and Middle Coal Measures, and many of them occur in England, as *P. arborescens*, *P. oreopteridia*, &c.

Asterotheca and *Scolecopteris* are clearly Marattiaceous, but could not be placed in any existing genus.

Ptychocarpus, Weiss, 1869.

(Plate II., fig. 22.)

Ptychocarpus, Weiss, "Foss. Flora d. jüngst. Stk. u. d. Rothl.", p. 94.
,, Zeiller, "Flore foss. d. bas. houil. d. Valen.", p. 40, fig. 26.
Stichopteris, Weiss, "Foss. Flora d. jüngst. Stk. u. d. Rothl.", p. 96.

Description.—Fertile and sterile pinnules similar, sporangia almost cylindrical, very slightly tapered at the summit, from 5-8 surrounding a very prominent receptacle to which they are united in all their length and attached to each other by their lateral faces.

Remarks.—The synangia are sometimes disposed in two parallel rows on each pinnule, sometimes in many rows on the large compound pinnules—to the number of four on each side of the medial nerve. As the synangia stood up prominently from the surface of the pinnules, in consequence of pressure they are often bent over on the veins.

* See plate i., fig. 7, *Marattia*.

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M. Renault has shown, from the examination of a silicified specimen, that the sporangia which compose the synangia are completely united among themselves to a central receptacle into which extends an axile vascular bundle.*

This type of fructification has only been observed in certain Pecopterids of the Upper Coal Measures, which belong to the group of *Diplazites*, Göppert; but as this genus has been founded on characters derived from the nervation, and probably contains other types of fructification than that just described, it cannot be employed for those species which are generically distinguished by the structure of the fruit.

Ptychocarpus unitus, Brongt., sp., is frequent in the Upper Coal Measures of England.

CALYMMATOTHECA, Stur, *emend.*, 1877.

(Plate II., fig. 23; Plate III., fig. 37.)

Calymmotheca, Stur, "Culm Flora," vol. ii., p. 255 (*in part*).
,, ,, "Zur Morph. u. Syst. d. Culm u. Carbon Farne," p. 167 (*in part*).
,, ,, "Carbon Flora," vol. i., p. 236 (*in part*).
Calymmatotheca, Zeiller, *Ann. d. Sci. Nat.*, 6e sér., Bot., vol. xvi., p. 182, 1883.
,, ,, "Flore foss. d. bas. houil. d. Valen.", p. 34, fig. 22, 1888.
,, Kidston, *Trans. Roy. Soc. Edin.*, vol. xxxiii., p. 137, 1887.
Sorocladus, Lesquereux, "Coal Flora," p. 327, 1880 (*in part*).

Description.—Fertile and barren pinnæ dissimilar; fertile pinnæ completely deprived of the limb; sporangia borne at the extremities of the ultimate ramifications of the secondary pinnæ, exannulate, large, oblong or linear, with thick walls whose cells are elongated in the direction of the longer axis, and united at their base round a common point of attachment. The synangia are composed of from 5-20 sporangia.

Remarks.—The sporangia appear to be attached around a small circular expansion of the extremity of the pedicel which bears them. They are quite free in their upper portion, but united to each other at their base. In *Calymmatotheca asteroides*, Lesqx., sp., there are usually six sporangia in a synangium, but in *C. bifida*, L. and H., sp., as many as twenty enter into its composition.

* Renault, *Ptychocarpus (Pecopteris) unita*, Brongt., sp. "Cours d. Botan. Foss.", 1883, p. 119, plate xx., figs. 11-19.

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Dr. Stur has explained this fruit as consisting of so many segments of a split involucre, but, from the examination of many excellently preserved British specimens of the genus, there remains no doubt in my mind as to the sporangial nature of the component parts of this fructification, an explanation of their structure which was first given by Renault,* and later more fully illustrated by Zeiller.†

In Britain there are three species, which, from their fructification, are known to belong to *Calymmatotheca*:—*C. affinis*, L. & H., sp.; *C. bifida*, L. & H., sp.; and *C. asteroides*, Lesqx., sp. The fruit of the first was discovered by the late Mr. C. W. Peach in fine condition in the Midcalder Oil Shales, and described before the Bot. Soc. of Edin. as *Staphylopteris Peachii*, Ether. and Balf., being then considered a distinct plant, but it is now known to be the fruit of *Sphenopteris affinis*, L. & H.‡ The second species, *C. bifida*, has been found in fruit in the Lower Carboniferous of both Scotland and England, and has been described by myself; while the third, *C. asteroides*, has been collected in the Middle Coal Measures of England near Dudley by the late Mr. Henry Johnson. The affinities of *Calymmatotheca* are clearly Marattiaceous, and in their cup-like synangia they show some resemblance to the synangia of *Kaulfussia*, but in the latter the synangia are scattered on the back of the fronds whose limb is not in any way reduced or modified, and further in *Kalfussia* the sporangia are *united laterally* throughout their whole length.

In *Calymmatotheca*, on the other hand, the sporangia are borne on specially modified pinnæ, entirely deprived of their foliage, and are only united to each other at the base.

As far as my observation has gone, these fruiting pinnæ are only produced at the base of the frond.§

* Renault, *loc. cit.*, p. 198, plate xxxiii., figs. 17 and 18.

† *Loc. cit.*

‡ These specimens were subsequently figured and described by Mr. Peach—*Quar. Journ. Geol. Soc.*, vol. xxxiv., p. 131, plate viii.

§ See *Trans. Roy. Soc. Edin.*, vol. xxxiii., plate viii., fig. 1. (*C. bifida*, L. & H., sp.)

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CROSSOTHECA, Zeiller, 1883.

(Plate II., fig. 24.)

Crossotheca, Zeiller, *Ann. d. Sci. Nat.*, 6e sér., Bot., vol. xvi., p. 180.
,, ,, "Flore foss. d. bas. houil. d. Valen.", p. 33, fig. 21.
Sorotheca, Stur, "Zur Morph. und Syst. d. Culm u. Carbon Farne," p. 175.
,, ,, "Carbon Flora," vol. i., p. 273.
Sorocladus, Lesqx., "Coal Flora," vol. i., p. 327 (*in part*).

Description.—Fertile and barren pinnules dissimilar, the fertile pinnules having the limb much reduced or suppressed. Sporangia exannulate, tapering to a point at the apex, contiguous or more or less united among themselves, and suspended like a fringe from the margin of the fertile pinnule.

Remarks.—This genus has been fully described and figured by Zeiller from specimens from the coal-fields of the north of France.

The sporangia of *Crossotheca* are linear oblong, with the base slightly broader than the apex. Their walls are composed of cells elongated in the direction of the axis. According to Zeiller they appear to be united in pairs or perhaps in fours at the extremities of veins that are given off from a swelling of the pedicel, which terminates in a thickening in the centre of the fertile pinnule.

It is only lately that I have been able to include this genus in the British Palæozoic Flora. A few months ago I received from Mr. W. Hemingway, for examination, a small collection of Middle Coal Measure ferns from the neighbourhood of Barnsley, and among them I was pleased to find several examples of a small fern in fructification, which is evidently to be referred to *Crossotheca*.* This species differs from the other described members of the genus in several well-marked characters. It also offers an interesting example of how different in appearance the barren pinnules may be in the several members of the same genus.

In *Crossotheca Crepini*, for example, the barren pinnules are divided into several rounded lobes, whereas in the species from Yorkshire, which I previously named *Crossotheca fimbriata*, but have since found to be identical with Stur's *Calymmatotheca Schatzlarensis*, the barren pinnules are divided into narrow linear segments.†

* See *Annals and Mag. Nat. Hist.*, ser. 6, vol. ii., pp. 23 and 24, plate i., figs. 1-8.

† The true position of the plant is in *Crossotheca*.

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I have just referred to Dr. Stur's interpretation of the structure of the fruit of *Calymmatotheca*, and here again he would apply the same explanation, but the views advocated by this author are altogether untenable by those who have had opportunity of examining well-preserved specimens of *Crossotheca*.

Renaultia, Zeiller, 1883 (Aug.).

(Plate II., fig. 25.)

Renaultia, Zeiller, *Ann. d. Sci. Nat.*, 6e sér., Bot., vol. xvi., p. 185, plate ix., figs. 16 and 17.
,, ,, "Flore foss. d. bas. houil. d. Valen.", p. 28, fig. 15, 1888.
Hapalopteris, Stur, "Zur Morph. und Syst. d. Culm u. Carbon Farne," p. 28 (issued Dec. 1883).
,, ,, "Carbon Flora," vol. i., p. 26, 1885.

Description.—Sporangia ovoid, either isolated or arranged in groups of from 2-5 at the extremity of the nerves towards the margin of the pinnule.

The walls of the sporangia are formed of cells elongated in the direction of the axis, but towards the apex the cells are more polygonal.

Remarks.—The foliage of the known species belonging to this genus is Sphenopteridian.

The hexagonal cells at the apex of the sporangia are very similar to those occurring at the apex of the sporangia of *Angiopteris*, but they are not differentiated to form an annulus.

The members of the genus hitherto discovered in Britain are *Renaultia (Sphenopteris) microcarpa*, Lesqx., sp. ("Coal Flora," p. 281, plate xlvii., fig. 2), the fruit of which was described by myself (*Ann. and Mag. Nat. Hist.*, ser. 5, vol. x., p. 9, plate i., figs. 9-14, 1882, and *Proc. Roy. Phys. Soc. Edin.*, vol. vii., p. 131, plate i., figs. 9-14 (excl. figs. 7 and 8 = *S. amœna*, Stur, sp.) from specimens discovered by Mr. James Bennie at Blairpoint, Dysart, Fife (Lower Coal Measures); and *Renaultia (Sphenopteris) gracilis*, Brongt., which was originally described by Brongniart from the mines near Newcastle-on-Tyne ("Hist. d. Végét. Foss.", p. 197, plate liv., fig. 2), of which the fruit has been observed by Renault ("Cours d. Botan. Foss.", 3e an., p. 190, plate xxxiii., figs. 1-4).

In the structure of the sporangia this genus has affinities with *Angiopteris*, but the arrangement of the fruit is very different.

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DACTYLOTHECA, Zeiller, 1883.

(Plate II., fig. 26.)

Dactylotheca, Zeiller, *Ann. d. Sci. Nat.*, vol. xvi., p. 184, plate ix., figs. 12-15.
,, ,, "Flore foss. d. bas. houil. d. Valen.", p. 30, fig. 16.
Senftenbergia, Stur (*not* Corda), in "Culm Flora" (*in part*), "Carbon Flora," and "Morph. und Syst. d. Culm u. Carbon Farne."

Description.—Sporangia ovoid, exannulate; tapered to a point at the summit, and attached to the secondary veins a little distance above their origin. Cells of the sporangia wall elongated in the direction of the greater axis, among which is a longitudinal band of cells more elongated than the others, and in the direction of this line the sporangia open at maturity.

Remarks.—The fertile pinnules do not differ in form, or only very slightly, from the barren ones. The sporangia cover a considerable part of the under surface of the pinnules—and not only occupy their marginal portion, but lie lengthwise on the nerves, not placed to the right or left of them as in *Renaultia*, from the sporangia of which those of *Dactylotheca* further differ in being more elongated and having a band of more elongated cells.

The type of this genus is *Pecopteris dentata*, Brongt., which is frequent in the Upper and Middle Coal Measures of England.

The affinities of *Dactylotheca* also appear to be with *Angiopteris*.

CYCLOTHECA, Kidston, 1888.

(Plate II., fig. 27.)

Cyclotheca, Annals and Mag. Nat. Hist., July, 1888, p. 26, plate i., figs. 10-12.

Description.—Sporangia small, free, sessile, circular, exannulate, and arranged in two parallel rows.

Remarks.—This genus has been founded on a single specimen collected by Mr. P. Jack at Ellismuir, Baillieston, from shales above the Kiltongue Coal. (Lower Coal Measures.)

The fossil consists of several alternate linear pinnæ, each pinna being only represented by the two parallel rows of sporangia, between which probably lay the midrib.

In the structure of the individual sporangia they closely approach to those of *Myriotheca*, Zeiller, and *Renaultia*, Zeiller (*Ann. d. Sci. Nat.*, 6e sér., Bot., vol. xvi., pp. 185-186), but in *Myriotheca* the sporangia are oval and cover the *whole* of the

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lower surface of the pinnule, and in *Renaultia* they are situated singly or in groups at the end of the veins. In *Cyclotheca*, on the other hand, the sporangia are circular and arranged in two long parallel rows. The specimen on which I have founded this genus has been named from these characters, *Cyclotheca biseriata*, Kidston.

Cyclotheca is Marattiaceous, but has not a very close relationship with any existing genus.

Myriotheca, Zeiller, 1883.
(Plate III., fig. 28.)

Myriotheca, Zeiller, *Ann. d. Sci. Nat.*, 6e sér., Bot., vol. xvi., p. 186, plate ix., figs. 18-20.
,, ,, "Flore foss. d. bas. houil. d. Valen.", p. 32, fig. 19.

Description.—Sporangia independent, exannulate, ovoid, sessile, covering the whole under surface of the pinnule; one sporangium placed beside the other without any apparent order.

Remarks.—The sporangia have a slightly elongated band of cells, at which part they seem to have opened for dehiscence. They appear to have been attached to the limb without any special receptacle.

The type of the genus *(M. Desaillyi)* belongs to the Sphenopterideæ, but the barren condition of the species is unknown, no barren pinnules having been found in union with the fruiting ones.

The genus, as learnt from the structure of the sporangia, is more closely related to *Angiopteris* than any other recent genus, but from this it differs much in the arrangement of its sporangia. It is, however, clearly Marattiaceous.

Myriotheca has not yet been observed in Britain.

Sphyropteris, Stur, 1883.
(Plate III., fig. 29.)

Sphyropteris, Stur, "Morph. und Syst. de Culm u. Carbon Farne," p. 23.
,, Stur, "Carbon Flora," vol. i., p. 16.
,, Zeiller, "Flore foss. d. bas. houil. d. Valen.", p. 31, fig. 17.
,, Kidston, *Trans. Roy. Soc. Edin.*, vol. xxxv., p. 402, plate i., fig. 3*a-d*.

Description.—Sporangia free, exannulate, sessile, placed on oblique elevated distant bands on a narrow membranous expan-

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sion, which is situated at right angles to the midrib of the pinnæ or pinnules "like a hammer on its handle."

Remarks.—On a specimen of this genus (*S. obliqua*, Marrat, sp.) from the Middle Coal Measures, St. Helen's, near Liverpool, and now in the Liverpool Museum, the arrangement of the sporangia is clearly exhibited. The wall of the sporangium is composed of elongated cells which tend to a point at the apex. In some cases I have observed what seems to be a small terminal depression at the apex of the sporangium, and, though I cannot positively affirm that this depression is a terminal pore similar to what occurs in the fossil genus *Urnatopteris* and in the recent genus *Danæa*, still the appearance is so like that which occurs on some of my specimens of *Urnatopteris* that the idea is suggested that in *Sphyropteris* the dehiscence took place by a terminal pore. This point can only be determined by the discovery of better specimens. The sporangia show no trace of an annulus.

Among recent ferns there is none with which *Sphyropteris* can be compared in the curiously developed expansion on which the fruit is placed and in the arrangement of the sporangia, but should it be proved that dehiscence took place by a terminal pore, its affinities would be with *Danæa*.

I am indebted to the Curator and Trustees of the Liverpool Museum for kindly forwarding this and many other specimens to me for examination.

I have collected another member of this genus in fruit (*S. Boehnischi*, Stur) at Furnace Bank, Old Sauchie Tower, near Alloa. (Lower Coal Measures.)

All the species known to belong to *Sphyropteris* are Sphenopteroid in the character of their barren foliage.

URNATOPTERIS, Kidston, 1884.

(Plate III., fig. 30.)

Urnatopteris, Kidston, *Quar. Journ. Geol. Soc.*, vol. xl., p. 594.
,, Zeiller, "Flore foss. d. bas. houil. d. Valen.", p. 33, fig. 20.

Description.—Barren and fruiting fronds (or pinnæ) dissimilar; fruiting fronds (or pinnæ) deprived of the limb, and bearing along the secondary rachis of the pinnæ two parallel alternate rows of free, oval, exannulate sporangia which open by a small circular terminal pore for the dissemination of the spores.

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Remarks.—The affinities of this interesting fructification are with the recent genus *Danæa*, in which, however, the fruit forms sessile synangia, which are immersed, linear, contiguous, occupying nearly the entire length of the venules and covering the whole under surface of the fertile fronds. In *Danæa* also the synangium consists of two rows of numerous laterally and oppositely connate sporangia, which united into a concrete mass form a linear synangium, each component sporangium of which opens by a circular terminal pore.

The fronds of *Danæa* attain from 1-3 feet in length, and are of firm texture; thus the recent genus in its general appearance forms a marked contrast to the delicate Sphenopteroid fern (*Sphenopteris tenella*, Brongt.) which is the type of the genus *Urnatopteris*.

The fruiting specimens of this fern, on which the genus was founded, were discovered some years ago in considerable plenty and in an excellent state of preservation, at Furnace Bank Colliery, Old Sauchie, near Alloa (Lower Coal Measures).

More recently Mr. Peter Jack has collected a good fruiting example at Scrawhill Colliery, near Airdrie. (Lower Coal Measures.)

ARCHÆOPTERIS, Dawson, 1882.

(Plate III., fig. 31 and fig. 32.)

Archæopteris, Dawson, "Plants of the Erian (Devonian) and Upper Silurian Formations of Canada," part 2, p. 98, 1882.
Palæopteris, Schimper (*not* Genitz), "Traité," vol. i., p. 475.
Cyclopteris, Forbes (*in part*), *Brit. Assoc. Report*, 1858, p. 75.

Description.—Frond very large, bipinnate, fruiting and barren pinnules dissimilar. *Barren* pinnules obovate, inequilateral, and contracted into a stalk-like slightly decurrent pedicel. Veins numerous, radiating from the base and dichotomising several times. The margin of the pinnule is generally more or less lacerated. *Fruiting* pinnules usually entirely deprived of the limb, and composed of a strong rachis-like vein on whose upper side are borne numerous oblong, blunt or pointed, sessile or shortly stalked, free, exannulate sporangia. The free barren extremity of the fruiting pinnules usually ends in several simple or divided thread-like filaments. The fertile pinnæ occupy the lower portion of the frond and usually bear one or two barren pinnules next the rachis, and a few at the apex of the

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pinnæ are also frequently barren. On the main axis, between the pinnæ, are placed larger pinnules of the same general structure as those on the pinnæ. At the base of the rachis, which appears to be smooth, are two large stipules—one on each side (Plate III., fig. 32).

Remarks.—From several circumstances, this is one of the most interesting of palæozoic ferns. It was first described by Forbes in 1852 under the name of *Cyclopteris Hibernica* (*Brit. Assoc. Report*, 1852, p. 43), and since that time has passed under several generic names. *Archæopteris Hibernica* is one of the characteristic fossils of the yellow sandstones of the South of Ireland whose geological position is not clearly decided—some classifying them as Upper Old Red Sandstone, others with the Lower Carboniferous. Sufficient to us is the fact that in *A. Hibernica* is one of the oldest British palæozoic ferns, and of which there is almost complete information as to its fruit and external form.

The examination of this fern makes one very much inclined to say that there is nothing new under the sun, for there is combined in this plant all the essential characters of the recent Marattiaceæ.

While making a comparison between *A. Hibernica* and the recent Marattiaceæ, let us at once dismiss from our minds the difference in the form of the barren pinnules, as this is a matter of very secondary importance, and not of generic value.

First, as to the fruit. In *A. Hibernica* the sporangia are narrow, oval, sessile, or very short stalked, and usually pointed at both extremities, though occasionally they appear to be blunt. The structure of these sporangia approaches therefore more closely to those of *Danæa* and *Marattia* than to any other Marattiaceous existing genera, but in *Palæopteris* the sporangia are not identical with either of these, nor are they united to form a synangium.

Again, a most typical Marattiaceous character in *Archæopteris Hibernica* is the presence of the two large stipules at the base of the rachis. There are several fine specimens showing the stipules in the Collection of the Geological Survey of Ireland, and there is also another specimen which, from its peculiar condition of preservation, shows scattered distant vascular bundles like so many strands or threads running up the rachis. This specimen has probably suffered a slight decay of the more delicate cellular tissue before being fossilized, which has admitted of the vascular bundles being exposed as they are now seen. All the characters

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just mentioned show that *A. Hibernica*, whose fronds attained a very large size, is clearly Marattiaceous and in its characters does not differ, as far as can be seen, in any of the essential marks from the recent members of that order.

The genus *Archæopteris* is widely distributed, occurring in Canada, the United States and Belgium, as well as in Ireland, and extending from the Devonian to the Coal Measures.

UNATHECA, Kidston, *genus nov.*

(Plate III., fig. 33.)

Ptychocarpus, Kidston (*not* Weiss), *Trans. Roy. Soc. Edin.*, vol. xxxiii., p. 350.

Description.—Frond tripinnate (?); pinnæ sub-opposite, lanceolate; pinnules sub-opposite, oblong, usually bearing four pairs of oblong lobes and a terminal one. On each lobe is situated an oblong sporangium, placed horizontally, which opens by a longitudinal cleft.

Remarks.—The type of this genus was collected at Camerton, Somerset, from the "Radstock Series," of the Upper Coal Measures, and in my paper "On the Fossil Flora of the Radstock Series of the Somerset and Bristol coal-field," was provisionally placed in Weiss' genus *Ptychocarpus*. Subsequent investigation has shown that it must be removed from this genus, and the genus *Unatheca* is now proposed for it. It was originally described as *Ptychocarpus oblongus*, Kidston.*

Each pinnule bears an oblong sporangium placed horizontally and surrounded by the very narrow border of the limb of the pinnule. The sporangia (on the only specimen collected) show a longitudinal depression, presumably arising from a cleft, by means of which dehiscence has taken place. This cleft does not extend to the two ends, from which I have inferred that there is only one sporangium here, and not two lying in close proximity.

If my interpretation of this fructification be correct, the fern is Marattiaceous, but does not seem to have close affinity with any recent genus.

* *Op. cit.*, p. 350, plate xx., figs. 2, 2*a*.

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C. GENERA OF UNCERTAIN AFFINITES.

ZEILLERIA, Kidston, 1884.

(Plate III., fig. 34.)

Zeilleria, Kidston, *Quar. Journ. Geol. Soc.*, vol. xl., p. 590, plate xxv.
,, Zeiller, "Flore foss. d. bas. houil. d. Valen.", p. 57, fig. 37.
Calymmotheca, Stur (*in part*), "Zur Morph. und Syst. d. Culm u. Carbon Farne," p. 167.
,, Stur (*in part*), "Carbon Flora, vol. i., p. 236.

Description.—Involucres placed at the extremities of certain lobes of the pinnules, which are slightly produced to form a pedicel. In the earlier condition the involucres are globose and closed, but at maturity split into four valves. The structure and arrangement of sporangia are unknown.

Remarks.—Of this interesting fructification only the structure of the involucres is known; we are in ignorance as to the arrangement of the contained sporangia or spores. The species known to belong to this genus have all very delicate Hymenophyllaceous pinnules, but, in the absence of fuller knowledge of the fructification, their systematic position remains uncertain.

The genus is interesting, however, as proving the existence of an involucre among palæozoic ferns, which in its structure approaches very closely to that of the capsules of the Hepaticæ.

The type of the genus is *Sphenopteris delicatula*, Sternb., and the specimens on which the genus is founded originate from the Forest of Wyre, Worcestershire, and are preserved in the Collection of the British Museum.

CHORIONOPTERIS, Corda, 1845.

(Plate III., fig. 35.)

Chorionopteris, Corda, "Flora d. Vorwelt," p. 90, plate liv., figs. 10-15.
,, Zeiller, "Flore foss. d. bas. houil. d. Valen.", p. 58.

Description.—Sorus globular, terminal, composed of four ovoid sporangia enclosed in a thick-walled capsule formed by the prolongation of the nerve, at first entirely closed but subsequently opening into four valves.

Remarks.—This curious and anomalous fructification was ascribed to the Gleicheniaceæ by Corda and to the Cyatheaceæ by Schimper.* Zeiller, on the other hand, who enters fully into

* "Handb. d. Palæont.", vol. ii., p. 93.

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the discussion of the affinities of this fossil, rejects the view that it has relationship with either of the genera mentioned above, and questions if it may not be Rhizocarpian.*

As far as I understand the plant there is little evidence for referring *Chorionopteris* to the Homosporous ferns. It may belong to that group, but if so there are no existing genera with which it can be compared, and it may with equal propriety be referred to the Heterosporous Filicaceæ as an aberrant form, though there does not appear to be sufficient known about the fossil to enable one satisfactorily to refer it to either group. As pointed out by Zeiller, the capsule, whose wall is composed of several layers of cells, appears to be formed from an extension of the vein and not to originate from the epidermal cells as in the Leptosporangiate ferns.

I include this very problematical genus here with the object of comparison with the genus *Zeilleria*. In this latter genus there is a true fern whose involucre splits into four valves. Beyond this, however, there are no data for a further comparison. The position of the fruit on the frond of *Zeilleria* also appears to be very different from that of *Chorionopteris*.

NEUROPTERIS, Brongt., 1822.

(Plate III., fig. 36.)

Neuropteris, Brongniart, "Sur la Classification des Végétaux Fossiles," p. 33, 1822.

The only fruiting specimen of this large and common Coal Measure genus that has yet been described, is the imperfect example of *Neuropteris heterophylla*, Brongt., found by Mr. T. Stock in the Lower Coal Measure shales, Blairpoint, Dysart, Fife, and described by me sometime ago.†

The fossil shows an axis about 8 cm. long, which gives off apparently two pairs of lateral pinnæ. The terminal portion of the specimen ends in a number of dichotomous branchlets—the ultimate divisions being about 8 mm. long, and bearing the fruit at their summits. On the terminal part of the fossil there is no trace of the ordinary foliage pinnules. On the lower part of the specimen are shown what appears to be the remains of a pair of lateral pinnæ, each of which seems to have supported four

* Zeiller, *op. cit.*, p. 58.

† *Trans. Roy. Soc. Edin.*, vol. xxxiii., p. 150, plate viii., fig. 7.

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fructifications. Associated with these pinnæ are the remains of a small number of ordinary barren pinnules. Of the two lower pinnæ, one is very incomplete, and only shows some fragments of the ordinary barren pinnules; the corresponding opposite pinna is, however, more perfect, and shows three fructifications and a portion of a pedicel of a fourth. At the base of this pinna are preserved some remains of the ordinary barren pinnules. It would appear, therefore, that each of the lateral pinnæ supported four fruits; and, on the terminal portion, though the remains of only eleven fructifications are seen, there were probably originally twelve. There may be combined in this part two lateral pinnæ and the apex of the frond, each bearing four fruits, but this cannot be clearly traced. On the same slab was another fragment of the fructification, but it is not shown in the figure here given.

In the description of this specimen I have refrained from employing the terms *indusium* or *sporangium* to the little expansions at the extremities of the pedicels, as I cannot determine their true structure, though they are apparently composed of two or four segments.

From the imperfect preservation of this fossil, it is quite impossible to form any conjecture as to the affinities of this genus; but Renault, from the examination of silicified specimens of the rachis of *Neuropteris*, has shown that they are Marattiaceous.*

Dicksoniites, Sterzel, 1881.

Dicksoniites, Sterzel, "Palæont. Char. d. ob. Steink. u. d. Rothlieg im erzgeb. Beck.", p. 74.
,, ,, *Botan. Centralbl.*, vol. xiii., no. 8/9, p. 317.
,, ,, *Zeitsch. d. deutsch. geol. Gesell.*, vol. xxxviii., p. 797.
,, Zeiller, "Flore Foss. d. bas. houil. d. Valen.", p. 62.

The fruit of *Pecopteris Pluckenetii*, Brongt., has been described by Sterzel, for which he has founded the genus *Dicksoniites*, but it is very imperfectly known. The fruit is situated at the extremities of the veins, and appears to consist of a raised circular collar in which were contained the sporangia, which were perhaps attached to a central receptacle. Probably this cup-shaped involucre was closed in the earlier stages of its development. In a fruiting specimen of this species which I received from Mr. E. Wilson, Clifton, collected at Welton, Somerset, and which shows the

* "Cours d. Botan. Foss.", 3e an., 1883, p. 169.

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upper surface of the pinnules, the fructifications are seen to have been placed in little pockets which project like knobs on the upper surface of the pinnules.

Dicksoniites Pluckenetii, Brongt., sp., is not of unfrequent occurrence in the Upper Coal Measures at Radstock.*

SECTION III.

FERN STEMS.

Three genera of Tree Fern Stems occur in the British Coal Measures—

I. *Caulopteris*, Lindley and Hutton.
II. *Megaphyton*, Artis.
III. *Psaronius*, Cotta.

The first two genera are founded on external characters, derived from the form and arrangement of the frond scars, and the last on its internal organization.

I. Caulopteris, L. and H., 1832.

(Plate III., fig. 38.)

Caulopteris, Lindley and Hutton, "Fossil Flora," vol. i., p. 121.
Ptychopteris, Corda, "Flora d. Vorwelt," p. 76.
Stemmatopteris, Corda, "Flora d. Vorwelt," p. 76.
Sigillaria, Brongniart (*in part*), "Hist. d. Végét. Foss.", vol. i., p. 392.

Description.—Stems of arborescent ferns bearing distant or contiguous, circular or oval, smooth scars, arranged quincuncially, containing—

Type 1.—An inner circular or oval closed ring more or less following the contour of the frond scar; within this is a second oval scar, open at its upper aspect, the free ends being bent inwards, and forming the "horse-shoe" scar.

Type 2.—A closed inner circular or oval line, within which is a variously bent transverse scar. Stems of both types bearing numerous aërial rootlet cicatrices, placed on the stem between the frond scars.

Scars on stems deprived of their outer envelope, oval or elongate-elliptical, upper and lower extremities rounded or pointed, and generally confluent, occasionally showing within the scar traces of an inner oval cicatrice; whole stem striate.

Remarks.—Several explanations have been given of the struc-

* See *Trans. Roy. Soc. Edin.*, vol. xxxiii., p. 383.

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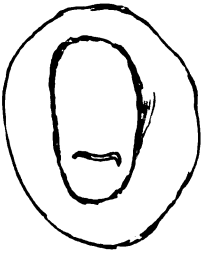
ture of the frond scars of *Caulopteris*, some maintaining that the large inner circle of the frond is closed; others, that its superior margin is open, and that the two free ends bend inwards, and thus form the characteristic "horse-shoe" scar. Both of these descriptions of the structure of the scars appear to be correct. Zeiller was the first to demonstrate the closed nature of the inner circle of the scar of *Caulopteris*,* inside of which he detected a bent transverse band, which latter he regarded as the true vascular cicatrice. Grand 'Eury, however, states in his "Flore Carbonifère du Departement de la Loire, et du Centre de la France,"† that, though in the Upper Coal Measures of the Centre of France the *Caulopteris* with "horse-shoe shaped" inner scars are very rare, they do exist, and on such a specimen he founds his *Caulopteris protopteroides*, remarking at the same time that this form of *Caulopteris* was not so plentiful in France as he had seen it in England. Grand 'Eury was further able to show, from the examination of a silicious specimen of *Caulopteris*, that the inner closed circle, as well as the transverse central scar, is a vascular tract.



Caulopteris peltigera, Brongt., sp. Scar showing inner closed vascular tract, within which is contained the transverse cicatrice. (After Zeiller, half natural size.)

The genus has, as far as I am aware, only been found in England in the Upper Coal Measures, and represented by those species with the "horse-shoe" form of scar.

Another very interesting point has been brought out by Zeiller, in his paper to which reference has already been made, that those fossils for which Corda proposed the genus *Ptychopteris* (of which *Caulopteris macrodiscus* is the type) only represent the inner portion of *Caulopteris*, corresponding probably to the sheath of *sclerenchyma* which surrounds the peripheral portion of the stem. The figures Zeiller gives of *Caulopteris patria* ‡ and of *C. endorhiza*,

* "Note sur quelques troncs de Fougères fossiles." *Bull. Soc. Géol. d. France*, 3e sér., vol. iii., p. 574, 1874-5.

† Page 84.

‡ *Bull. Soc. Géol. d. France*, 3e sér., vol. iii., plate xvii., fig. 4. This is named on the plate *Caulopteris peltigera*, Brongt., sp. (?), but has since been described as a new species by Grand 'Eury under the name of *Caulopteris patria*. See also Zeiller, "Végét. foss. d. Terr. houil.", p. 100; and Grand 'Eury, "Flore Carbon. du départ. de la Loire," &c., p. 87.

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Grand 'Eury,* show very beautifully the union of these two genera on the same specimen. On plate viii. of the work just mentioned is given an exceedingly fine example of a *Caulopteris* exhibiting the fronds attached to the stem.† This fine specimen confirms the accuracy of the position assigned to those fossils by Lindley and Hutton.

The internal structure of these stems is probably of the *Psaronius* type.

The genus *Caulopteris* is represented by a greater number of species on the Continent than in Britain. The only British species I have yet met with are—

Caulopteris primæva, L. and H.

Caulopteris primæva, Lindley and Hutton, "Fossil Flora," vol. i., plate xlii.

Loc. Radstock and Camerton, Somerset.

Hor. Upper Coal Measures.

Caulopteris anglica, Kidston.

Caulopteris anglica, Kidston, *Trans. Roy. Soc. Edin.*, vol. xxxiii., p. 392, plate xxvi., fig. 3.

Loc. Radstock and Camerton, Somerset.

Hor. Upper Coal Measures.

Caulopteris cyclostigma, Lesqx.

Caulopteris cyclostigma, Lesquereux, "Coal Flora of Pennsyl.", vol. i., p. 341.

Loc. Radstock and Camerton, Somerset.

Hor. Upper Coal Measures.

The *Ptychopteris* condition of these stems also occurs at the above localities, and has been included under the name of *Caulopteris macrodiseus*, Brongt., sp., in my paper on the Fossil Flora of the Radstock Area,‡ but it must not be regarded as a distinct species from the above, but only their decorticated condition, the specific identification of which it is often difficult to determine in this state.

* "Etudes sur le Terrain houiller de Comentry," vol. ii.; "Flore Fossile," by Renault and Zeiller, première partie, by R. Zeiller; *Bull. de la Soc. de l'Industrie minerale*, St. Etienne, 1888, plate xxxvi.

† *Loc. cit.*, *Pecopteris Sterzeli*, Zeiller.

‡ *Trans. Roy. Soc. Edin.*, vol. xxxiii.

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II. Megaphyton, Artis, 1825.

(Plate III., fig. 39.)

Megaphyton, Artis, "Antedil. Phytology," p. 20.

Description.—Trunks bearing two opposite vertical rows of frond-scars; scars containing the vascular cicatrice, variously arranged and sometimes not well defined, but constant in its characters in the different species.

Remarks.—The only British specimens I have yet seen are English, and originate from the Middle and Upper Coal Measures. The genus requires a thorough revision as far as the British species are concerned. I therefore refrain from giving any list of the British representatives.

The type of *Megaphyton* is the *Megaphyton frondosum*, Artis,—from a Sandstone quarry, near Rowmarsh, Yorkshire—the counterterpart of which is preserved in the British Museum.

III. Psaronius (Cotta *emend.*) Göppert, 1864.

(Plate III., fig. 40.)

Psaronius, Cotta, "Die Dendrolithen," p. 27, 1832.
,, Göppert, "Foss. Flora d. Perm. Form.", p. 46, 1864.
,, Schimper, "Traité d. Paléont. Végét.", vol. i., p. 716.
,, ,, in Zittel, "Handb. d. Palæont.", vol. ii., p. 148.
,, Corda, "Flora d. Vorwelt," p. 94.
,, Renault, "Cours d. Botan. Foss.", 3e an., p. 142, 1883.
,, Grand, 'Eury "Flore Carbon. du départ. de la Loire," &c., p. 92.

Description.—Stem generally thick, sometimes with a diameter of several feet. The principal mass of the stem formed of parenchymatous tissue, permeated with numerous adventitious rootlets, which arise from the usually numerous, central, bent and strap-shaped, concentrically arranged, vascular bundles. The vascular system, in relation to the bark is small, round or angular. Outer surface of trunk covered with numerous aërial rootlets.

Remarks.—The outer surface of the stems of *Psaronius* is clothed with a dense covering of aërial rootlets, similar to what is found on recent tree-fern stems—especially on their lower part. The vascular strands composing the vascular system, are of different form in the various species—being in transverse section sometimes single or double "horse-shoe" shape, their ends being often bent inwards—sometimes sinuous, strap-shaped or nearly straight.

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The genus is more common in the Permian than in the Carboniferous formation.

Psaronius is very rare in Britain, and even the most perfect specimens found in this country are very fragmentary. These have been described by Professor Williamson as *Psaronius Renaultii.*

Psaronius is Marattiaceous, but differs from the recent Marattiaceous ferns in having a high erect stem. In the existing representatives the stem is but feebly developed. The large size of the vascular bundles, and their arrangement in *Psaronius* is also dissimilar, but the structural peculiarities of *Psaronius* would indicate its union with this group.

Psaronius Renaultii, Will.

Psaronius Renaultii, Will., *Phil. Trans.*, 1876, vol. clxvi., p. 10, plate iii., figs. 18, 20, 21 ; plate iv., figs. 19, 22*x*, 22, 22*xx*.
Psaronius, Will., ibid., part II., 1883, p. 464, plate xxx., fig. 16.

Remarks.—Only fragments of the stem of this species have been found, but the arrangement of the bundles appears to be similar to that which maintains in the other *Psaronii.* In a specimen discovered by Mr. G. Wild—the most perfect that has yet been found—the bundles are long and narrow, and bent into a flattened semicircle, their ultimate ends being further rolled inwards. This bundle has been surrounded by phloem sheath. In the ground tissue which surrounds the bundle are numerous resin or gum canals.

It is probable that *Psaronius* is a *Caulopteris* with its internal structure preserved.

Loc. From the Lancashire coal-field.

FERN PETIOLES.

Fern petioles showing their internal organization are of frequent occurrence at those localities in Britain where Carboniferous plants having their structure preserved are found, and many have been described by Dr. Williamson from Yorkshire and Lancashire as well as from Pettycur, Fifeshire.

The original workers founded a number of genera for the inclusion of such specimens, grounding the generic characters on the arrangement and form of the vascular bundles. Such a classification is, however, for scientific purposes entirely useless, for it is

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found among recent ferns that the arrangement of the vascular bundles varies much in the same genus.

Certain recent genera contain species, the petioles of which, when examined in transverse section, show the vascular bundles to be arranged in very diverse manners. Conversely to this it is found that in genera which are quite distinct from each other, the arrangement of the vascular bundles is similar or identical. Therefore Dr. Williamson classifies together under the name of *Rachiopteris* all fern petioles which have sometimes been treated as belonging to distinct genera. From the present standpoint of our knowledge this is much the preferable course to take.

Time will not allow of our examining the various types of fern petiole structure in detail, but I have selected two—one representing the Annulate or Leptosporangiate ferns, the other the Exannulate or Eusporangiate ferns.

Structure of Existing Leptosporangiate Fern Petioles and Stems.

Let us now examine the structure of recent Leptosporangiate fern petioles or rhizomes, taking as our type *Pteris aquilina*, Linn.

The fundamental tissue of the fern stem is in great part composed of thin-walled parenchyma, but certain portions become differentiated from the rest, and their cells become firm and prosenchymatous *(sclerenchyma)* with much thickened walls of a brown colour. In transverse section this species shows two elongated narrow tracts of sclerenchyma situated on each side of the centre of the stem, between which are two of the three chief tracts of vascular tissue, and outside of one of the tracts of sclerenchyma is another principal vascular bundle; in addition there are a number of smaller vascular tracts or bundles forming an irregular circle outside those just described. The stem is surrounded by a thick layer of sclerenchyma which is thinned at two points where the fundamental tissue extends to the epidermal layer.

The xylem of the bundle rarely contains true vessels with perforated walls; it consists chiefly of long broad scalariform tracheids with occasionally bordered pits. True vessels do, however, occur in *P. aquilina* with the septa perforated in a scalariform manner.

At certain points between, but especially outside of, the scalari-

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form tracheids, are found a few spiral and narrow tracheids. Within the bundle and mixed with the tracheids are frequently narrow thin-walled cells which contain starch.

The xylem is surrounded by phloem (bast) containing parenchymatous cells as well as sieve tubes. Between the phloem and the xylem is a layer of cellular tissue containing starch, and outside of the phloem (or bast) portion of the bundle is another layer of starch containing parenchymatous cells; and enclosing all is the bundle-sheath or *endodermis.* The last-mentioned layer is very distinct; the cells early become transformed into cork, and have usually a brownish colour.

The bundles in their course through the stem anastomise and form the so-called *netted cylinder.*

From the circumstances that the phloem surrounds the xylem on all sides, these bundles are called *concentric.**

Excluding minor differences such is the typical structure of Leptosporangiate fern stems. In some, however, as in *Lastrea Filix-mas*, there is no sclerenchyma and in some other ferns the sclerenchyma is colourless.

In *Osmunda* the arrangement of the bundles differs somewhat from that which maintains in most of the other Leptosporangiate ferns, the bast portion of the bundle being only placed on that side of the xylem that faces outwards. Such bundles, from having the bast only on one side of the xylem are called *collateral.*

Structure of Fossil Leptosporangiate Petioles.

A considerable number of fern petioles belonging to this group have been described by various authors—but especially by Cotta, Corda, Renault, Grand 'Eury, and Williamson. Britain has perhaps produced a greater number of species than any other country, and these have been mostly fully and ably described by Professor Williamson in his Memoirs "On the Organisation of the Fossil Plants of the Coal Measures" which have appeared from time to time in the *Philosophical Transactions.* As these papers are very accessible, and should be studied by all students of fossil botany, only one or two of the many species that have been described are treated of here in detail, but references to other British species are given.

* Figures of transverse and longitudinal sections of *Pteris aquilina* are given in most handbooks on Structural Botany.

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RACHIOPTERIS, Williamson.

Vascular bundle H-shaped, or some modification of that form.

(ZYGOPTERIS, Corda.)

The fern petioles included in this group have the vascular bundle more or less prominently arranged in the form of an H, or what has been described as the "double-anchor" arrangement. In such species as *Rachiopteris Lacattii*, Renault, sp., or *R. di-upsilon*, Will., this is strongly marked. In *R. duplex*, though the form of the bundle is more hour-glass shaped, it must also be included in this section.

In the earlier part of this paper it was pointed out that the form of the bundle was quite insufficient for generic distinction, and no better proof of the truth of this statement could be found than the *Rachiopteris Grayii*,* Will., which was described in his last Memoir.†

Rachiopteris Lacattii, Renault.

(Plate IV., fig. 41.)

Rachiopteris Lacattii, Williamson, *Phil. Trans.*, vol. clxiv., 1874, p. 694, plate lvi., fig. 142; plate lvii., figs. 43-47; plate lviii., fig. 48; *ibid.*, vol. clxxx., 1889, p. 159; plate ii., fig. 6.

Zygopteris Lacattii, Renault, *Ann. d. Sci. Nat.*, 5e sér., Bot., vol. xii., p. 170, plate vii., fig. 12; plate viii., figs. 14-16; plate ix., fig. 13; "Cours. d. Botan. Foss.", 3e an., 1883, p. 101, plate xvi., fig. 1.

Description.—Petiole circular or oval, vascular bundle central, H-shaped in transverse section with the extremities of the two uprights generally bent inwards towards each other and forming the "double-anchor." The vascular bundle is surrounded by an "hour-glass shaped" tract of bast, which in turn is enclosed by the bundle-sheath. The space from the bundle-sheath to the periphery is occupied by cellular tissue, which, as it is traced outwards, gradually assumes the form of sclerenchyma, the sclerenchyma becoming specially characterised towards the periphery of the stem.

The tracheids of the cross-bar of the H-shaped vascular bundle are much larger than those of the arms, and are composed of *areolated* tracheids. In the two arms, the tracheids are very much smaller, especially in the outermost portion, from which the pinnæ bundles are given off. The larger tracheids in the arms are

* See next page. † *Phil. Trans.*, vol. clxxx., p. 155 *et seq.*, 1889.

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areolated, and the smaller are scalariform. It is frequently very difficult to find a term which completely describes the nature of the wall-thickenings in the tracheids composing the vascular system, as so many modifications occur through which one form passes into the other.

Surrounding the vascular system, and within the soft bast, are the sieve tubes which form two irregularly curved lines, whose position probably varies a little in different examples. Enclosing the vascular system is the bundle-sheath. The cellular tissue outside of and surrounding the bundle-sheath is tabular in longitudinal section, but as it is traced outwards the cells become elongated and gradually transform themselves into a surrounding subcortical *sclerenchymatous* sheath.

Outside of the central bundle and in the ground tissue of the stem is usually one or more isolated tracts of vascular tissue. These are the vascular tracts that go off to the pinnæ.

Remarks.—In this petiole we see all the essential characters, though modified in detail, of those occurring in the rachis of *Pteris aquilina*, Linn., which has been already examined.

In regard to the "*Zygopteris*" form of fern structure, annulate sporangia have been found in connection with it by Renault, but even without this direct evidence, the internal structure of the stem, when compared with that of recent genera, would lead us to suspect that its fructification would consist of annulate sporangia.

Rachiopteris Grayii, Williamson.

Rachiopteris Grayii, Will., *Phil. Trans.*, vol. clxxx., 1889, p. 155, plate i., figs. 1-5; plate ii., fig. 5*a*.

Anachoropteris Decaisnii, Will. (*not* Renault), *Phil. Trans.*, vol. clxiv., 1874, p. 699, plate lviii., fig. 51.

Remarks.—This species is of special interest, as from it Professor Williamson has been able to show that the rhizomes which were placed by Renault in his genus *Anachoropteris*,* give rise to stems with the "double-anchor" form of vascular bundle (*Zygopteris*). No two bundles could be more unlike in outer form than the typical bundle of *Zygopteris* and the five-rayed star-like bundle of *Anachoropteris*, but it has now been shown by Williamson that the latter gives birth to the former. In *Rachiopteris Grayii* there is a third form of bundle; these are circular, and are probably those of the rootlets.

* Renault, *Ann. d. Sci. Nat.*, 5e sér., Bot., vol. xii., p. 161.

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Rachiopteris bibractiensis, Renault, sp.

Rachiopteris bibractiensis, Will., *Phil. Trans.*, vol. clxiv., 1874, p. 697, plate lviii., figs. 49-50.

Zygopteris bibractiensis, Renault, *Ann. d. Sci. Nat.*, 5e sér., Bot., vol. xii., p. 171, plate ix., figs. 17-18.

Rachiopteris di-upsilon, Williamson.

Rachiopteris di-upsilon, Will., *Phil. Trans.*, part II., 1880, p. 537, plate xxi., figs. 90-91.

Rachiopteris duplex, Williamson.

Rachiopteris duplex, Will., *Phil. Trans.*, vol. clxiv., 1874, p. 687, plate liv., figs. 29-34, 36; plate lv., figs. 28, 35, 35*a*-35*b*, 35*c*, 35*f*, 37, 38, 40, 41; plate lvi., figs. 35*d*, 35*e*, 35*g*, 35*h*, 35*i*, 35*k*, 39, 41*a*.

,, *ibid.*, vol. clxxx., 1889, p. 159.

Arpexylon simplex, Will., *Phil. Trans.*, vol. clxiv., 1874, p. 690.

Rachiopteris insignis, Williamson.

Rachiopteris insignis, Will., *Phil. Trans.*, part II., 1880, p. 506, plate xvi., figs. 19, 20, 21, 22; plate xvii., fig. 23.

Vascular Bundle, Circular or Oval.

Rachiopteris corrugata, Williamson.

Rachiopteris corrugata, Will., *Phil. Trans.*, vol. clxvii., 1877, p. 213, plate v., figs. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 19; plate vi., figs. 13, 14, 15, 16, 17, 18, 21, 22; plate vii., figs. 20, 23, 24.

,, *ibid.*, vol. clxxx., 1888, p. 158.

Rachiopteris cylindrica, Williamson.

Rachiopteris cylindrica, Will., *Phil. Trans.*, part II., 1878, p. 350, plate xxiv., figs. 80-85.

Rachiopteris robusta, Williamson.

Rachiopteris robusta, Will., *Phil. Trans.*, part II., 1880, p. 505, plate xvi., fig. 23*a*.

Rachiopteris hirsuta, Williamson.

Rachiopteris hirsuta, *Phil. Trans.*, vol. clxxx., 1889, p. 160, plate i., fig. 15; plate ii., fig. 11; plate iv., figs. 9, 10, 12, 13, 14.

Rachiopteris gleichenioides (?), Corda, sp.

Rachiopteris gleichenioides, Will., *Phil. Trans.*, part II., 1878, p. 350, plate xxiv., fig. 79.

Chorionopteris gleichenioides, Corda, "Flora d. Vorwelt," p. 90, plate liv., figs. 10-15.

Rachiopteris Oldhamia, Binney, sp.

Rachiopteris Oldhamia, Will., *Phil. Trans.*, vol. clxiv., 1874, p. 685, plate liii., figs. 20-24, 25*a*, 25*b*; plate liv., figs. 25, 26, 27.

Stauropteris Oldhamia, Binney, *Proc. Phil. Soc. Manchester*, vol. xi., p. 69.

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Rachiopteris asper, Williamson.

Rachiopteris asper, Will., *Phil. Trans.*, vol. clxiv., 1874, p. 679, plate li., figs. 1-5; plate lii., figs. 6-13; plate liii., figs. 14-16.
,, *Phil. Trans.*, vol. clxxviii., 1887, p. 298.
Edroxylon, Will., *Proc. Roy. Soc.*, no. 136.

Description of fully developed rachis. Rachis oval, with superior surface flattened. Vascular system in transverse section "gutter-shaped" (consisting of a slightly convex transverse bar, from the ends of which spring two upright diverging bands). Periphery of rachis surrounded by a band of narrow-celled sclerenchymatous tissue arranged in wedges, separated from each other by narrow extensions of the parenchymatous tissue which occupies the area between the vascular bundle and the outer surface of the rachis. Outside of these wedges is an epidermis of two rows of cells. Situated within this parenchymatous tissue are numerous lenticular lacunæ, which, in the earlier condition of the plant, are filled with delicate parenchyma. The outer surface of the rachis bears numerous spine-like hairs, formed of several layers of small-celled parenchyma. Vascular bundle composed of reticulate, barred and spiral vessels; the two latter forms generally situated towards the periphery of the bundle. In the younger stems there are generally two oval vascular bundles directed obliquely towards each other. Foliage small, Sphenopteridian.

Remarks.—There is a probability that this rachis belongs to *Sphenopteris Höninghausi*, Brongt.,* and that the following species is the rhizome or stem of the same plant.

DICTYOXYLON, Williamson.

Dictyoxylon, Williamson, *Monthly Microscopical Journ.*, Aug. 1869, p. 67.

Dictyoxylon Oldhamium, Binney, sp.

(Plate IV., figs. 42 and 43.)

Dictyoxylon Oldhamium, Will., *Monthly Micro. Journ.*, vol. ii., Aug. 1869, p. 66, plate xx., figs. 3-4.
,, *Brit. Assoc. Report*, 1871.
Dadoxylon Oldhamium, Binney, *Proc. Lit. and Phil. Soc. Manchester*, 1866.
Lyginodendron Oldhamium, Will., *Phil. Trans.*, 1873, p. 377, plate xxii., figs. 1-5; plate xxiii., figs. 6-9; plate xxiv., figs. 10-13, 15; plate xxv., figs. 14, 16, 17, 19, 20, 21; plate xxvi., figs. 18, 22-25.

* "Hist. d. Végét. Foss.", p. 199, plate lii. Andræ, "Vorwelt Pflanzen," p. 13, plates iv.-v.

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Lyginodendron Oldhamium, Will., "On some Anomalous Oolitic and Palæozoic Forms of Vegetation," *Proc. Roy. Inst. of Great Britain*, vol. x., 1883, p. 7, fig. 7.

Description.—In small stems (or rhizomes?) the pith is at first very small or scarcely discernible, and is surrounded by a ligneous zone—the primary vascular system. As the stem (or rhizome?) increases in size, it is accompanied by a considerable increase in the dimensions of the pith, which is composed of polygonal cells, arranged somewhat in vertical rows. With the increase of the pith in volume, the primary vascular bundle becomes split into segments, which are carried outwards by the increasing pith, and eventually they appear as so many isolated vascular tracts irregularly placed around the periphery of the pith. The largest vessels of the primary bundle are those surrounding the pith.

Outside of the primary vascular bundle is developed a cambium layer, from which the secondary ligneous zone is formed. This zone forms a complete circle, the vessels next to the cambium being smaller than those more distant. This bundle is divided into wedges—sometimes very narrow—by numerous prominent medullary rays, frequently of several layers in thickness. This zone contains a greater proportion of medullary rays than of ligneous tissue. The vessels are reticulated.

The bark consists of three zones;—an inner parenchymatous zone, a middle sclerenchymatous zone, and an outer parenchymatous zone. The inner parenchymatous zone consists of delicate cells, and is characterised by the presence of denser-walled, irregular star-shaped patches of cellular tissue. Within this zone and close to the secondary vascular circle are three to five, but generally four, separate vascular tracts. They are usually each composed of two bundles, slightly separated, but may be formed of only one bundle. These isolated vascular tracts also increase by exogenous growth. The component vessels are chiefly reticulated, but along with these are smaller ones of the barred type. The second zone of the bark consists of narrow wedges of sclerenchyma, much elongated and thickened by internal deposits of lignine. These are separated from each other by narrow tracts of the parenchymatous tissue. The sclerenchymatous bands in their vertical course anastomise and form a netted cylinder. The last and outermost zone of the bark consists of parenchymatous tissue. No true epidermal layer has yet been observed.

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The outer surface of the stem is ornamented with fusiform or lozenge-shaped elevations. (Plate IV., fig. 43.)

Remarks.—The isolated bundles in the inner zone of the bark are supposed to originate in the same, and it seems most probable that they are the bundles which go off to the leaf-organs.

Dr. Williamson, from the fusiform elevations on the outer surface of the bark, as figured by him,* identified his genus *Dictyoxylon* with Gourlie's genus *Lyginodendron.*† I have examined Gourlie's type, and feel satisfied that it is only a fragment of an old *Lepidodendron* in a similar condition to that figured by Dawson ‡ and those described by myself in the *Ann. and Mag. Nat. Hist.* § from which I believe Williamson's *Lyginodendron* to be very distinct. Also Corda's figure of *Sagenaria fusiformis* ‖ which Williamson regards as generically identical, must be excluded, as it is a true *Lepidodendron.*

Although treating *Dictyoxylon Oldhamium* as a distinct species, there appears to be very little room for doubting that it is the stem or rhizome which produced the petioles described under the name of *Rachiopteris asper*,¶ about which there is no doubt as to their belonging to a true fern, as the pinnules have been found attached to them. I give here, for comparison with the outer surface of *Lyginodendron Oldhamium*, a figure of a portion of a large rachis of *Sphenopteris Höninghausi* (Plate IV., fig. 44), the outer surface of which is divided into fusiform or rhomboidal areas, in the centre of which is a little dot, from which the spiny thorn-like scale has fallen.**

Those interested in this subject must consult Dr. Williamson's Memoir†† in which the structure of *Lyginodendron* is most fully and ably described.

* *Loc. cit.*, plate xxvii., 1873.

† *Proc. Phil. Soc. of Glasgow*, vol. i., p. 108, 1841-44.

‡ "Acadian Geol.," 2nd ed., 1868, p. 455, fig. 170*c*.

§ Vol. xvi., page 166-7, 1885. ‖ "Flora d. Vorwelt," plate vi., fig. 4.

¶ This view is also held by Williamson (*Phil. Trans.*, vol. clxxviii., 1887, p. 298), and Count de Solms.

** Since this paper was read, Professor Williamson announced at the meeting of the British Association, Newcastle, 1889, that he had now absolute evidence that the small fern petioles, named *Rachiopteris asper*, were the branches of *Dictyoxylon Oldhamium.* This announcement carries with it the more important discovery, that in the stem of a Carboniferous fern we have undoubted evidence of the presence of a *cambium layer.*

†† *Loc. cit.* iv., 1873.

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Dictyoxylon (?) *anomalum*, Williamson, sp.

Lyginodendron (?) *anomalum*, Will., *Phil. Trans.*, part II., 1878, p. 352, plate xxv., figs. 90, 91, 92.

HETERANGIUM, Corda.

Corda, "Beitr. z. Flora d. Vorwelt," p. 22, 1867.

Heterangium Grievii, Williamson, sp.

Dictyoxylon Grievii, Will., *Brit. Assoc. Report.*, 1871.
Heterangium Grievii, Will., *Phil. Trans.*, 1873, p. 394, plate xxviii., figs. 30, 31, 34, 46; plate xxix., figs. 32, 33, 35; plate xxx., figs. 36-44; plate xxxi., figs. 45, 47, 49.
,, Will., *Phil. Trans.*, 1872, p. 283.
,, Will., *ibid.*, vol. clxxviii., 1887, p. 298.

Remarks.—This is a most interesting species, but as *Dictyoxylon Oldhamium* has been described so fully, the student must refer to Professor Williamson's Memoir for a description of this plant. I would only point out that one of the characteristic points in the structure of this species—the dark transverse bars of thickened tissue in the cortex—occur in *Sphenopteris elegans*, Brongt., and in *S. grandifrons*, Sauveur. Of the former, fine specimens showing this character have been figured by Stur.* I have no doubt as to *Heterangium Grievii* being a fern rachis.

Heterangium Tilioides, Williamson.

Heterangium Tilioides, Will., *Phil. Trans.*, vol. clxxviii., 1887, p. 289, plate xxi., figs. 1, 3, 4, 6, 10, 16, 19; plate xxii., figs. 2, 5, 7, 8, 11, 13, 14, 15, 17, 18; plate xxiii., figs. 9, 12.

KALOXYLON, Williamson.

Phil. Trans., vol. clxvi., 1876, p. 23.

Kaloxylon Hookeri, Williamson.

Kaloxylon Hookeri, Will., *Phil. Trans.*, vol. clxvi., 1876, p. 13, plate iv., fig. 29; plate v., figs. 23-27; plate vi., figs. 28, 30-33; plate vii., figs. 34-38.
,, Will., *ibid.*, vol. clxxviii., 1887, p. 293, plate xxiii., figs. 20, 21, 24, 25, 26, 29, 29*a*; plate xxiv., figs. 22, 27, 28, 30, 31, 32, 33, 33*a*, 34, 34*a*, 35, 35*a*, 36, 36*a*, 37, 37*a*.

Remarks.—The position of this fossil is not satisfactorily determined, but it is probably a type of fern structure.

* "Culm Flora," plate xxx., fig. 5; plate xxxi., fig. 4.

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Structure of the Stem of Existing Marattiaceæ.

For this group *Marattia laxa*, Kunze, may serve as our type.

The fundamental tissue consists of thin-walled parenchyma, in which the separate vascular bundles are arranged in two or more circles, the inner circles being somewhat irregular.

A sclerenchymatous tissue forms a complete sub-epidermal circle, but at certain parts of its course much larger cells of sclerenchymatous tissue form radial tracts in the band. This layer is separated from the epidermis by a band of cellular tissue of 8-10 cells in thickness. Scattered throughout the stem, both in the sclerenchymatous and fundamental tissue, are numerous gum canals.

The xylem consists of scalariform tracheids surrounded on all sides by phloem, in which the small sieve tubes are placed.

There is no endodermis (bundle-sheath), the absence of which character forms an important point of distinction between the Marattiaceous and the Leptosporangiate fern stem structure.

Structure of the Stem of Fossil Marattiaceæ.

As a typical fossil Marattiaceous fern stem *Myelopteris* may be taken.

Myelopteris, Renault.

Myelopteris, Renault, "*Etude du genre Myelopteris*," Mem. Acad. d. Sciences, vol. xxii., no. 10, 1875, plates i.-v.

,, "Cours. d. Botan. Foss.", 3e an., 1883, pp. 35 and 165, plate xxviii., figs. 2, 3.

,, Williamson, *Phil. Trans.*, vol. clxvi., p. 1, plate i., figs. 1, 2, 3, 4, 4*, 10, 12; plate ii., figs. 5, 6, 7, 7*, 8, 11, 16; plate iii., figs. 9, 13, 14, 15; plate iv., fig. 17.

The fundamental tissue is parenchymatous, in which are placed the vascular bundles. The outermost are placed in a circle, but those within this outermost circle are not so regularly placed.

The stem is surrounded by a sclerenchymatous sheath, which is separated from the epidermis by a layer of parenchyma of several cells in thickness. The sclerenchymatous band is formed of wedge-shaped portions, whose apices are directed towards the centre of the stem—their broader and outer ends being united among themselves to form a solid band. Immediately within this sclerenchymatous zone there are occasionally isolated scleren-

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chymatous tracts arranged concentrically. Scattered throughout the stem and sclerenchymatous zone are numerous gum canals.

The bundles are composed of a xylem portion (Plate IV., fig. 45*a*) formed of spiral vessels, and usually directed towards the centre of the stem and a phloem portion directed outwards. (Plate IV., fig. 45*b*.) All bundles do not, however, hold the same position in regard to the axis of the stem, but some are often placed obliquely to it. The phloem portion is rarely preserved, but its place is indicated by a large opening.

There is therefore in the bundles of *Myelopteris* (Plate IV., fig. 45), an arrangement similar to that which occurs in *Ophioglossum vulgatum* (Plate IV., fig. 46) and *Osmunda*, where the bundles are collateral.

The arrangement of the bundles, which are devoid of a bundle-sheath (though the cells of the ground tissue that immediately surround them are slightly smaller in size than those forming the other portions of the ground mass), and the presence of numerous true gum canals, show the Marattiaceous nature of the petioles under examination.

Some of these Myelopteroid stems with structure preserved fortunately had their pinnules attached, from which Renault was enabled to determine that they belong in part to *Alethopteris* and *Neuropteris*.

Conclusion.

Though the botanist who has hitherto confined his investigations to the study of recent ferns, might think the occurrence of a *cambium* or *meristem* layer and *medullary rays* in the stems of ferns an impossibility, still this is not so. In the fossil lycopods, the increase of the secondary vascular system by exogenous growth, is a constant character, and it was by this means they were enabled to attain to arborescent dimensions. The presence of a *cambium* among recent lycopods is still found in the genus *Isoetes*. In examining the fructification and structure of Carboniferous ferns, the comprehensive type of palæozoic fern structure cannot fail to impress itself on the observer. The structures there found in union, appear to have subsequently split up and gone in different lines.

Writing in regard to this subject Professor Williamson says, " . . . one thing is certain, viz., that in their internal

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organization they present combinations of tissues that find no representatives amongst living plants. Possibly they are the generalized ancestors of both ferns and cycads, which transmitted their external contours to the former and their exogenous modes of growth to the latter types. In considering this possibility we must not forget that in *Stangeria** we have a still living plant in which the stem of a cycad bears fronds, the leaflets of which retain the dichotomous nervation of a true fern. The *Stangeria* has retained, not only the primative exogenous stem of some ancestral type, in common with its other cycadean relatives, but also the peculiar fern-like leaflets, which may also have come down to it from palæozoic times. Hence we have here a combination of fern-like features and an exogenous mode of growth. Such being the case, it need not startle us if we have to conclude that a similar combination existed during the Carboniferous age."†

Before concluding this Memoir, I would wish to acknowledge the assistance which has been willingly afforded me in all cases by many brother botanists and geologists. In particular cases their names have been already mentioned, but to many my indebtedness is of such a nature that it cannot be individually stated, though none the less valuable, and to these I would now tender my sincere thanks. I cannot, however, omit mentioning the names of Professor Williamson; Mr. W. Cash, Halifax; and Mr. G. Wild, Brardsley.

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* I have been informed that the specimens of *Stangeria* which were first examined consisted only of fronds and were described as a fern. On the subsequent arrival of the fruit of the species it was found to be a cycad.

† *Phil. Trans.*, vol. clxxviii., 1887, p. 298.

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Note.—The woodcuts, fig. 1 and fig. 2, have been kindly lent by the Council of the Royal Society of Edinburgh, to whom my thanks are due.

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EXPLANATIONS TO PLATES.

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Plate I.

Fig. 1.—Sporangium of *Hymenophyllum Tunbridgense*, Sm. (enlarged). *a.* Annulus.

,, 2.—Sporangium of *Alsophila excelsa*, Br. (enlarged). *a.* Annulus.

,, 3.—Sporangium of *Polypodium vulgare*, Linn. (enlarged). *a.* Annulus.

,, 4.—Sporangium of *Todea Africana*, Willd. (enlarged). *a.* Annulus.

,, 5.—Sporangium of *Mertensia gigantea*, Presl. (enlarged). *a.* Annulus.

,, 6.—Sporangium of *Anemidictyon Phyllitidis*, J. Sm. (enlarged). *a.* Annulus.

,, 7.—*Marattia alata*, Sm. Synangium (seen from above and in section, slightly enlarged).

,, 8.—*Angiopteris erecta*, Hoffm. Synangium (seen from above and in section, enlarged).

,, 9.—*Danæa alata*, Sm. Synangium (seen obliquely and in section, enlarged).

,, 10.—*Kaulfussia Assamica*, Griff. Synangium (showing upper and lower aspect, enlarged). Figs. 1-5 and 7-10, after Hooker; fig. 6, after Luerssen.

,, 11.—*Annulate sporangium*, showing echinate spores. From the Coal Measures, Dulesgate (enlarged). (From a photomicrograph.)

,, 12.—*Annulate sporangium*, showing sub-triangular spores. From the Coal Measures, Halifax (enlarged). (From a photomicrograph.)

,, 13.—*Annulate sporangium*. From the Coal Measures, Halifax (enlarged). (From a photomicrograph of a specimen lent by Mr. W. Cash.)

,, 14.—*Hymenophyllites quadridactylites*, Gutbier, sp. Fruiting pinnule and sporangia (enlarged). After Zeiller.

,, 15.—*Oligocarpia Brongniarti*, Stur. *a.* Fruiting pinnules; *b.* and *c.* groups of sporangia; *d.* sporangium (all enlarged). After Zeiller.

,, 16.—*Senftenbergia elegans*, Corda. *a.* Fruiting pinnule; *b.* sporangium (both enlarged). After Corda.

,, 17.—*Corynepteris coralloides*, Gutbier, sp. *a.* and *b.* Portions of fruiting pinnules (enlarged); *c.* group of sporangia (more highly enlarged). After Zeiller.

,, 18.—*Zygopteris pinnata*, Grand 'Eury. Group of sporangia (enlarged); *b.* section of sporangium. After Zeiller.

,, 19.—*Schizostachys sphenopteroides*, Kidston. *a.* Two pinnules (natural size); *b.* sporangia (enlarged).

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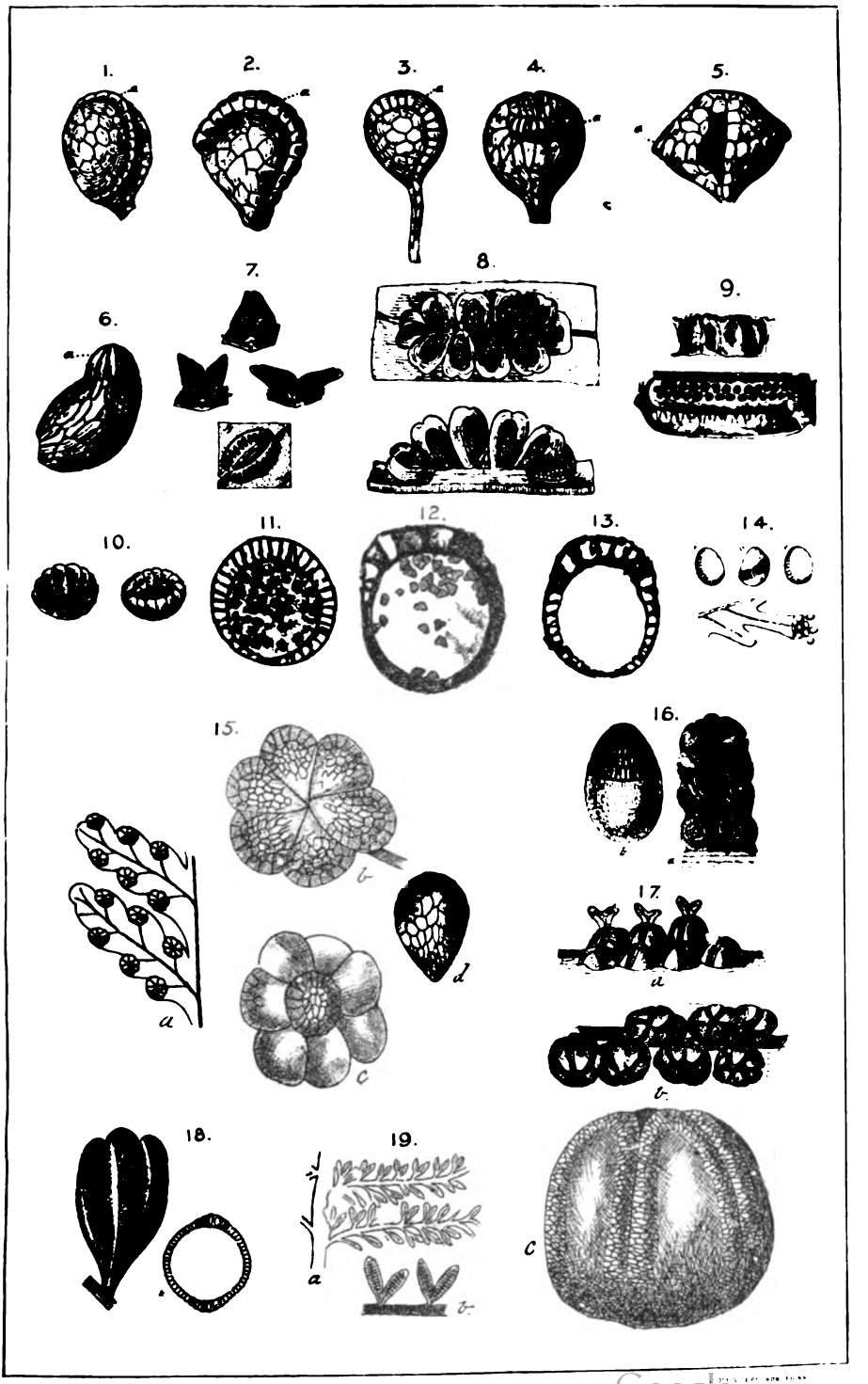

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Plate II.

Fig. 20.—*Scolecopteris*. *a. b. c. S. polymorpha*, Brongt., sp. *a.* Side view of synangia; *b.* transverse section of pinnule showing synangia; *c.* section parallel with surface of frond, showing arrangement of synangia. After Grand 'Eury. *d. e. Scolecopteris elegans*, Zenker. Transverse sections of fruiting pinnules. After Strasburger.

,, 21.—*Asterotheca abbreviata*, Brongt., sp. (= *Pecopteris Miltoni*, *Artis*). *a.* Portion of fruiting pinna; *b.* sporangia (both enlarged). After Zeiller.

,, 22.—*Ptychocarpus unitus*, Brongt., sp. *a.* Fruiting pinnules, the synangia bent over by pressure (enlarged); *d.* section of synangium. After Zeiller; *b.* fruiting pinnules seen from above; *c.* synangia seen from the side. After Grand 'Eury.

,, 23.—*Calymmatotheca*. *a. b. C. affinis*, L. and H., sp.; *c. d. C. bifida*, L. and H., sp.; *a. c. d.* (reduced); *b.* (enlarged to show the sporangia).

,, 24.—*Crossotheca Schatzlarensis*, Stur, sp. *a.* (reduced); *b.* synangium (enlarged); *c. Crossotheca Crepini*, Zeiller (enlarged). After Zeiller.

,, 25.—*Renaultia microcarpa*, Lesqx., sp. *a. b.* Fruiting pinnules; *c.* sporangium (all enlarged.)

,, 26.—*Dactylotheca dentata*, Brongt., sp. *a.* Fruiting pinnules; *b.* sporangium (all enlarged). After Zeiller.

,, 27.—*Cyclotheca biseriata*, Kidston. *a.* (reduced); *b.* sporangia (enlarged).

,, 28.—*Myriotheca Desaillyi*, Zeiller. *a.* Pinna bearing fructifying pinnules; *b.* two sporangia (enlarged). After Zeiller.

,, 29.—*Sphyropteris obliqua*, Marrat., sp. Fruiting pinnule (enlarged), (the sporangia are only shown on the right half); *b.* sporangium (enlarged).

,, 30.—*Urnatopteris tenella*, Brongt., sp. *a.* Fruiting frond (reduced); *b.* sporangia (enlarged).

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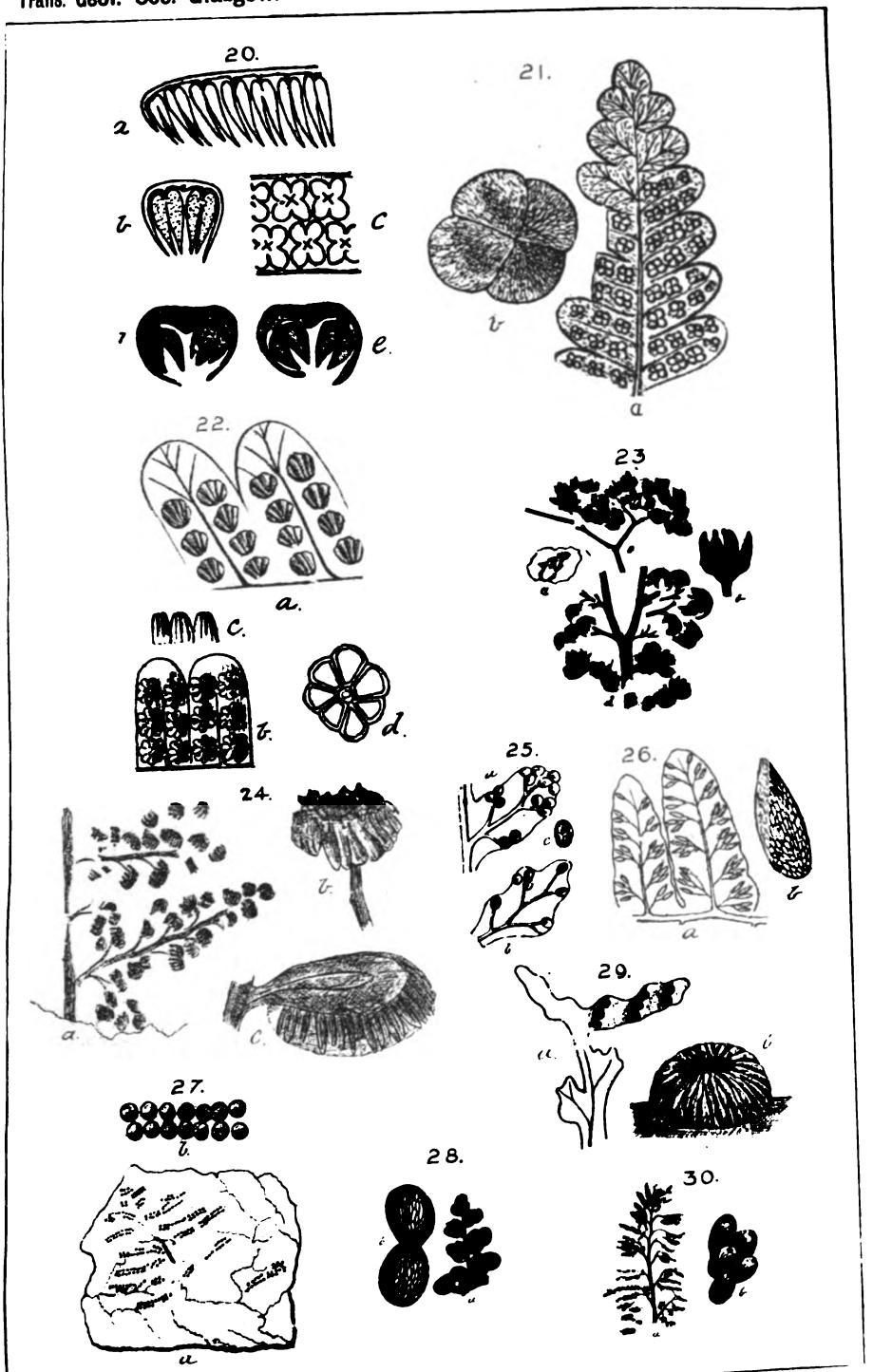

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Plate III.

Fig. 31.—*Palæopteris Hibernica*, Forbes, sp. *a.* Portion of fruiting pinna (reduced); *b.* fruiting pinnule; *c.* a few sporangia borne on the margin of a foliage pinnule; *d.* sporangia (enlarged). From specimens in the collection of the Geological Survey of Ireland, Dublin.

,, 32.—*Palæopteris Hibernica*, Forbes, sp. Base of a frond showing the stipules (much reduced). From a specimen in the collection of the Geological Survey of Ireland, Dublin.

,, 33.—*Unatheca oblonga*, Kidston. Two fruiting pinnules (natural size), and sporangium showing the longitudinal cleft (enlarged).

,, 34.—*Zeilleria delicatula*, Sternberg, sp. *a. b.* (Natural size); *d.* involucre (enlarged); *e. Zeilleria Aroldensis*, Stur, sp.

,, 35.—*Chorionopteris gleichenioides*, Corda. *a.* Vertical section of a capsule showing the sporangia containing the spores; *b.* exterior view of a closed capsule; *c.* longitudinal section of a fertile pinnule. After Corda.

,, 36.—*Neuropteris heterophylla*, Brongniart. Showing the fruiting portion, at the base of which are some barren pinnules (reduced).

,, 37.—*Calymmatotheca asteroides*, Lesqx., sp. Portion of a pinna showing four groups of sporangia (slightly enlarged). And a sporangium (much enlarged). After Zeiller.

,, 38.—*Caulopteris anglica*, Kidston. Showing the peltate scars with the inner horse-shoe-shaped vascular impression (reduced).

,, 39.—*Megaphyton MacLayi*, Lesqx., showing the vertical row of frond scars and the vascular impressions (reduced). After Zeiller.

,, 40.—*Psaronius Cottai*, Corda. Transverse section of portion of stem, showing central vascular axis of strap-shaped bundles, surrounded by parenchyma containing numerous rootlet bundles. After Schimper.

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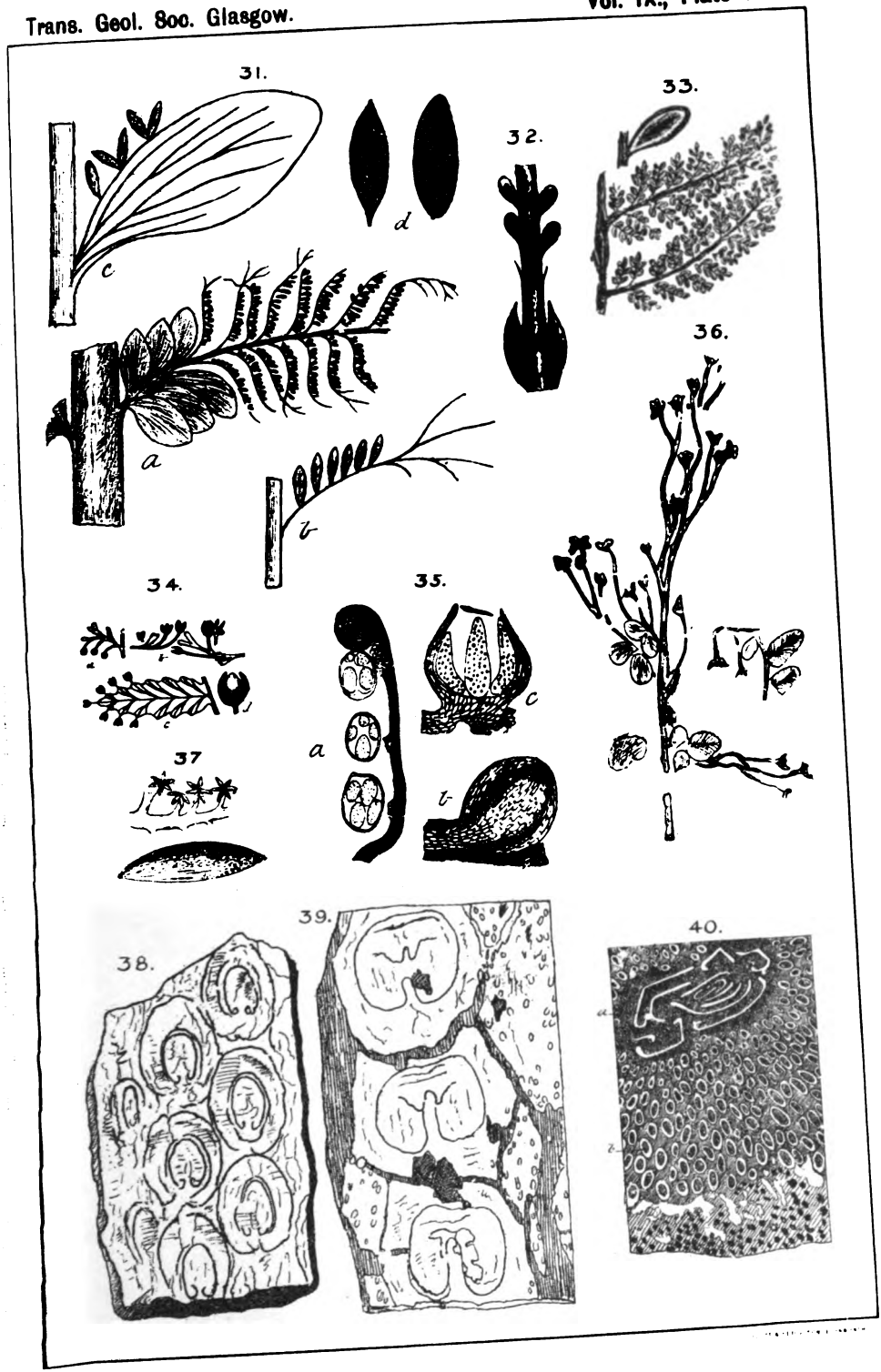

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Plate IV.

Fig. 41.—*Rachiopteris Lacattii*, Renault, sp. Portion of a transverse section of the rachis (enlarged).

a. Xylem portion of bundle.
b. Phloem portion of bundle.
c. Sieve tubes (?)
d. Bundle sheath.
e. Bundle going off to secondary rachis.
f. Outer bark.

Coal Measures, Halifax. (From a photomicrograph.)

,, 42.—*Dictyoxylon Oldhamium*, Binney, sp. Transverse section of portion of a stem (enlarged).

a. Medullary axis.
b. Medullary rays.
c. Vascular tissue.
d. Stem bundle.
e. Parenchymatous tracts of bark.
f. Prosenchymatous tracts of bark.
g. Medullary vessels.

Coal Measures, Halifax. (From a photomicrograph).

,, 43.—*Dictyoxylon Oldhamium*, Binney, sp. Outer surface of the stem. After Williamson (reduced).

,, 44.—*Sphenopteris Höninghausi*, Brongt. Portion of the rachis showing the outer surface bearing rhomboidal elevations, in the centre of which is a small dot, from which the spine-like scale has fallen. Middle Coal Measures, Netherton, Staffordshire. (From a photograph, slightly enlarged).

,, 45.—*Myelopteris*. Vascular bundle, transverse section.

a. Xylem portion of bundle.
b. Phloem portion of bundle, most of which has disappeared.
c. Ground tissue of stem.

Coal Measures, Oldham. (From a photomicrograph, enlarged).

,, 46.—*Ophioglossum vulgatum*, Linn. Vascular bundle, transverse section.

a. Xylem portion of bundle.
b. Phloem portion of bundle.
c. Ground tissue of stem.

(From a photomicrograph, enlarged).

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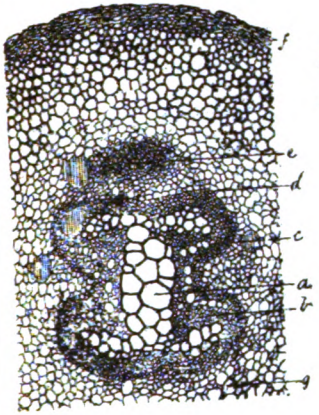
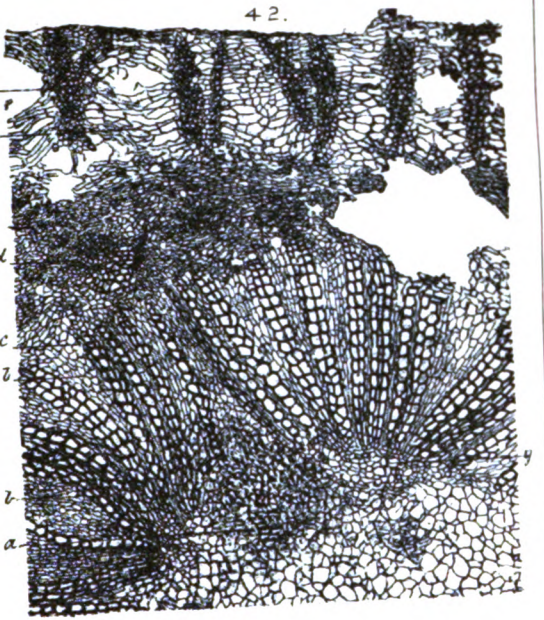


42.



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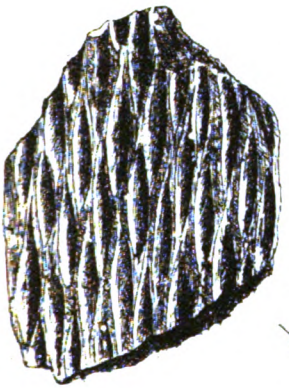

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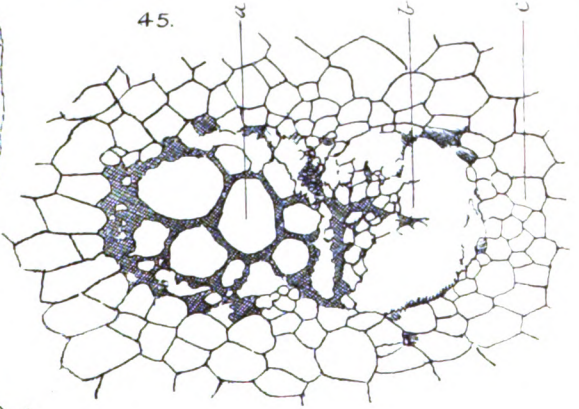

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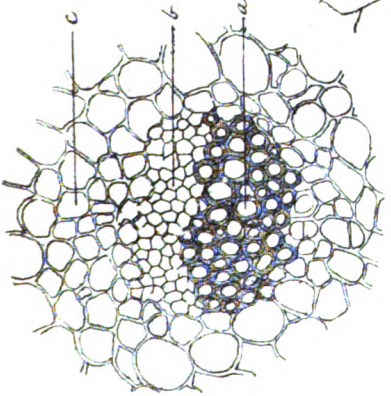

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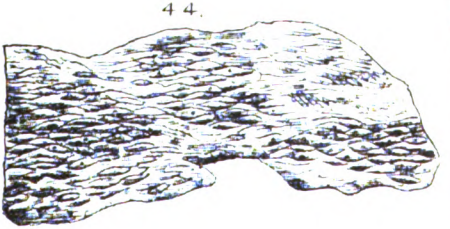

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No. II.—On the Internal Structure of the Carboniferous Corals forming the Genus *Chætetes* of Fischer.

By John Young, F.G.S., *V.P.*

[Read 26th May, 1890.]

The genus of Carboniferous corals, forming the *Chætetes* of Fischer, has long been known to palæontologists under, at least, three generic names, viz., *Favosites*, *Chætetes*, and *Alveolites*. They were first described by Fleming, in 1828, in his "British Animals," where he placed them in Lamarck's genus, *Favosites*. In 1837, Fischer established the genus *Chætetes* for a Russian Carboniferous coral—*C. septosus*, now believed to be identical with one of Fleming's species. Count Keyserling, in 1846, removed Fleming's species from *Favosites*, from their not having perfect walls for their corallites, and from the absence of *mural pores* in their walls as found in *Favosites*, and placed them with Fischer's *Chætetes*. In 1851, Professor M'Coy, in his "British Palæozoic Fossils," accepted Fischer's genus for Fleming's species, but in the same year, Milne Edwards and Jules Haime, in their Monograph on "Fossil Corals," issued by the Palæontographical Society, removed Fleming's species from *Chætetes* into *Alveolites* of Lamarck, retaining at the same time Fischer's genus *Chætetes* for his species *C. radians*, which, as above stated, is now believed to be identical with Fleming's British form—*C. septosus*. *Chætetes*, however, is now the genus most generally accepted by palæontologists for this entire group of Carboniferous corals.

During last year, I was led to make an independent examination of the structure of these corals, by means of transparent sections prepared by myself for examination under the microscope. I was induced to do this, owing to a somewhat bitter dispute which had arisen between Mr. James Thomson, F.G.S., of this Society, and Professor H. Alleyne Nicholson, of the University of Aberdeen, as to the presence, or absence, of what are termed *mural pores* in the walls of these corals. Mr. Thomson—in the *Proceedings of the Philosophical Society of Glasgow*, 1881 and 1888—has figured and described what he terms *mural pores*, of the same character as those found in the genus *Favosites*, in our Carboniferous *Chætetes* (or *Alveolites*, as he prefers to name it).

Professor Nicholson, on the other hand, denies the existence of these mural pores in Mr. Thomson's specimens, and states—in the

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Geological Magazine, vol. v., 1888, p. 110—"I have failed to find in a single instance any indication of any of the phenomena above-mentioned, as caused by the presence of mural pores. I have therefore no doubt that the corallites in the four species [mentioned by Mr. Thomson] possessed imperforate walls."

Mr. Thomson in his later paper (1888), above noted, re-asserts the existence of mural pores, and quotes Milne Edwards and Haime in support of his views, that the Carboniferous *Alveolites* "agree with Edwards and Haime's description, in possessing mural pores." I find, in referring to the Monograph of these authors, already noted, that while they place both *Chætetes* and *Alveolites* in Lamarck's family of the Favositidæ, yet neither in their descriptions of these genera, nor in those of the Carboniferous species, do they make any reference to the existence of mural pores in these corals, nor do they figure them in any of their illustrations. I may also state that, while they figure and describe mural pores in nearly all the species of *Favosites*, they omit them in their general description, as being in no way characteristic of all the genera now placed in the family of the Favositidæ.

I have no wish to make any other remarks on the points under dispute between Professor Nicholson and Mr. Thomson, except by stating that, so far as I have carefully sectioned and examined these corals, from the several districts of Scotland and England from which I have obtained specimens, I have failed in finding in their walls any traces of mural pores such as are characteristic of *Favosites*, or such as are figured by Mr. Thomson in his papers already quoted. I am, therefore, strongly inclined to agree with Professor Nicholson's opinion, that such mural pores do not exist in our British Carboniferous *Chætetes*.

I am, however, glad to be able to state that I have discovered, in the course of my investigations, that these corals possess an interesting internal structure of a different kind from that of the mural pores which characterise some of the genera forming the Favositidæ. This structure, which I have been fortunate in finding, exists only in well-preserved examples of the coral, and, so far as is known to me, has never hitherto been either figured or described. Briefly it consists of a numerous series of small short spines of varying lengths, which are seen to be planted in the walls and tabulæ of the corallites. Those on the walls project slightly outwards and upwards, whilst those on the tabulæ stand in a more or

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less erect position. None of the spines, within the area of the corallites, seem to have extended in length beyond the distance that separates one cross tabula from another. I have further discovered that these spines, in the better preserved specimens, were not solid, but tubular, and, when cut in cross section, their interiors are seen to be filled with a clearer calcite than that forming their walls. The first specimen which afforded me this new insight into the internal structure of *Chætetes* I owe to the kindness of Mr. John Angus, Irondale House, Muirkirk, from the limestone strata of which district it was obtained. It came to hand after I had sectioned many specimens from other localities, and in which I had failed to find mural pores, or other structure different from that already figured and described in connection with *Chætetes*.

This discovery encouraged me to go on making sections from all available specimens, so as to get a better idea of the state of preservation of the structure in these corals from the various localities. For the opportunity of doing so I am indebted to Dr. J. R. S. Hunter of Braidwood, and to Dr. D. Forsyth, who supplied specimens from the Muirkirk district; to Mr. Robert Craig, Langside, Beith, for specimens from the Ayrshire limestones; to Mr. James Bennie, of the Geological Survey, for specimens from the Bathgate and Dunbar limestones; and to Professor Alleyne Nicholson for specimens from the Shap Fells limestone. To these gentlemen, therefore, I severally return my best thanks.

I have now prepared, from these specimens, over 100 sections, cut in transverse and vertical directions, and a careful study of them clearly shows that in them are to be found nearly all the stages of preservation of the coral, from the most perfect condition in which the spine structure has yet been found, as in Mr. Angus's specimen, down through a series in which the internal structure has become more and more obliterated, until all trace of spines, and even of tabulæ within the walls of the corallites, has disappeared. The causes which have led to this obliteration of the finer structures of the coral may have been various. They may have been due to the percolation of waters through the porous mass ere fossilization had taken place, or to after changes through mineralization of the strata in which the organisms were embedded. I am, however, inclined to think that the greater part of the obliteration of the finer structures took place during the life of the later-growing portions of the coral, for, in all the specimens yet sectioned, I have

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only found the spine structure well preserved in, or near, the last-growing surface layers of the coral. Sections taken below this point show the spines gradually disappearing from the walls and tabulæ, till at the base and centre of the coral they are often entirely obliterated; or when traces of them are present, only the spine bases are preserved, appearing in the walls as a series of small dots, which, when viewed under the microscope by transmitted light, look like dark spots, or like white spots by reflected light. Had obliteration of the spine structure not taken place until after the final death of the outer-growing portions of the coral, it would have been difficult to explain why the outer surface layers have the structure better preserved than those of the interior, for if the obliteration was entirely due to fossilization, or to other mineral changes after death, one would naturally expect the outer surface would have been first affected. This, however, is seen not to be the case.

In some localities *Chætetes* is often found in a more or less silicified condition. When this is the case, the internal structures have generally suffered great alteration, both spines and tabulæ being obliterated. In such silicified specimens we sometimes find that the walls of the corallites have been wholly or partly replaced by silica, which has been deposited on the walls, in the form of numerous minute, rounded "blebs" or dots of microscopic size, and slightly raised above the surface of the walls. Those who are in search of mural pores in this coral might readily mistake these raised points of silica for the openings of pores, and possibly they have been mistaken for such, but microscopic sections clearly show that they never were pores, but mere incrusting points of silica, having a ring-like structure, and of the chalcedonic type. I may here mention that all the better-preserved specimens of *Chætetes* seem to have been enveloped in a calcareous shale, whilst those found in the purer limestones have had their structure more or less obliterated through crystallization of the limestone. This condition of preservation seems to hold good in the case of the other Carboniferous organisms which I have sectioned, the finer structures being generally obtained from the shale beds of the limestone series.

Having thus briefly indicated some of the conditions under which these corals have been found, and that the finer structures seem to have been very perishable, and are seldom preserved, I

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shall now shortly point out those characters found in well-preserved examples, both on the surface and in the body of the structure. In the Muirkirk specimens preserved in shale, examples often turn up showing the polygonal cell-openings of the corallites on their outer surface, and, where such cells have been cleaned out by weathering, their boundary walls can usually be examined. These are seen to have originally had a loosely porous and spinose structure, and are now, in the better-preserved examples, clad with a numerous group of minute and slightly-raised tubercles—the bases of spines—which give to the outer margin of the cell-walls a roughened appearance, reminding one of the slightly-raised acanthopores found on the surface of some forms of the Monticulipora. Where this structure on the surface of *Chætetes* has been well preserved, the tubular character of the spines planted in the walls and tabulæ is best seen in transverse sections which have been cut at, or close to, this later-growing surface. As already stated, the spine structure is absent from the deeper portions of the coral, or is more or less obliterated, even in specimens where it is well preserved at the surface. In transverse sections, the number of spines found on the walls and tabulæ within the area of each corallite is very variable. In some a hundred or more may be counted, in others less than a dozen, but this decrease in numbers of the spines in any of the corallites, is due, I think, more to their obliteration after death than to their non-existence in life, for the best sections show clear evidence that in the living condition of the coral both walls and tabulæ were crowded by a structure of minute spines. As the tabulæ do not always occur on the same level in the corallites, transverse sections, therefore, never show more than those few with their spines which chance to be at the surface. In vertical sections the spines, as now preserved, are seen to be of varying lengths, both on the walls and tabulæ, but, owing to their being cut chiefly longitudinally, their tubular character is not so conspicuously visible as in the transverse sections, though their slanting bases, where they pass into the walls, can be seen as groups of small dark spots, from their slightly-denser structure. Another character, in many of the vertical and transverse sections, is the thickening of the walls of the corallites in parts by a secondary deposit of sclerenchyma. This is now chiefly found near the outer surface of the coral, and, when well preserved, the tubular spines are there seen to have existed in great numbers. Deeper down in

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the coral, the sclerenchyma often seems to have been dissolved away, evidently by the action of those agencies which, as already indicated, have obliterated all traces of spines and tabulæ. When this is the case, the walls of the corallites, in the deeper parts of the coral, look thin and naked when compared with sections cut near the surface, where the sclerenchyma and clothing of spines exist.

The evidence of the disappearance of structure, such as spines and tabulæ, from within the walls of the corallites, which is afforded by my various sections, will help to explain statements made by some former observers, such as that the tabulæ were often absent, rare, or remote, or that they had apparently never been developed. In some of these sections the total and partial disappearance of the tabulæ from within the walls of the corallites can be distinctly seen within certain altered areas of a single specimen.

The only other structural character which I have to note in connection with this coral is one seen in some of the better-preserved Muirkirk specimens. It consists of a system of minute thread-like canals which traverse the walls in a horizontal, wavy manner, and which are of a lighter colour than the calcite forming the walls; but whether this appearance is to be considered as the remains of a minute structure which once pervaded the walls is a point on which we require further enlightenment. Some of the sections from these specimens also show, that, during the growth of the coral, it was often infested by various other incrusting organisms of the limestone period, and which are found as thin patches between the layers of growth in the coral. They belong to three distinct organisms, viz., *Tabulipora Urei*, *Fistulipora incrustans*, and a minute, twisted, tubular organism which closely resembles *Girvanella*, a genus not yet recorded from the Carboniferous strata of Western Scotland. These incrusting organisms have evidently, for a time, caused interruptions to the growth of the living coral over the areas of surface to which they were attached, but in their turn they are seen to have been buried under the outer growths of the newer layers of the coral.

From what I have stated in the foregoing remarks regarding the structure found in the better-preserved examples of *Chætetes*, it will be seen that we have here an organism, in the walls of whose corallites there is an entirely different structure from that of the horizontal mural pores characteristic of *Favosites*, or of those which

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have been figured and described by Mr. Thomson as found in the Carboniferous *Chætetes*, but of which no corroborative proof seems to exist. The only other Carboniferous organism with a somewhat similar structure and arrangement of spines within the walls of its corallites, is, so far as I know, that of *Fistulipora incrustans*, Phill. (*F. minor*, M'Coy). This new structure in *Fistulipora*, I have, however, already noticed in a paper in the *Annals and Mag. Nat. Hist.*, April 1888, pp. 244-5.

I shall now conclude this paper by stating that some three or four species of *Chætetes* from Carboniferous strata have been described, but it is very probable that these are no more than varieties of one and the same coral produced by the more or less favourable conditions under which they lived. *Chætetes radians*, Fischer, is now believed to be identical with *C. septosus*, Flem., while, according to Professor M'Coy, *C. depressus*, Flem., is only a dwarfed condition, owing to slower growth of the same coral, its corallites, within a certain area, being more numerous and smaller than those of *C. septosus*, which is the only well-marked difference between the two species. In the sections which I have prepared there are considerable differences, both in the form and size of the corallites, even within the area of the same specimen when that happened to be large, but the spiny structure of the walls and tabulæ present the same characters in all the varieties—of which *C. septosus*, Flem., may be taken as the more common type.

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No. III.—Notes upon a Cutting in the New Kilbirnie Branch of the Lanarkshire and Ayrshire Railway, on the Farm of Gurdy, Beith. By Robert Craig, Langside, Beith, *Corresponding Member.*

[Read 13th December, 1888.]

Introduction.—The cutting on the above-named railway to which I wish to direct your attention is on the farm of Gurdy, Beith. It commences near where the railway crosses the Beith and Kilbirnie road, and extends for about three-fourths of a mile in an east-by-south direction, finally running out on the farm of Coalburn, Dalry. The greatest depth is on Gurdy farm, where it is nearly 30 feet deep; and as it intersects the strata at an oblique angle, it has cut through and exposed from 20 to 25 fathoms of the strata which lie above the lower limestone and below the workable clayband ironstone. The intersection of these strata is at the west or Kilbirnie end of the cutting, and terminates at a fault and downthrow where it crosses the Kerrsland glen and Pogree burn. The strata met with in the cutting, from this burn to its termination on Coalburn, belong to those which lie above the main coal of the Dalry field. Except vegetable markings, the sandstone and shales on the east end of the cutting are apparently non-fossiliferous.

The mineral and fossiliferous characters of the strata west of the Pogree burn have been closely anticipated in a previous paper by the author, "On the Strata between the Lower and Upper Limestones" (*Transactions*, vol. vii., page 86). In that paper is given a section of the strata exposed in Kerrsland glen, and in the Gurdy railway cutting the same strata are found. In the following notes regarding them I shall, where they correspond, give also the numbers by which they were distinguished in the glen section above mentioned.

Limestone no. 1; Glen section no. 11.—A few yards from the west end of the cutting a bed or band of limestone was laid open continuously for about 30 yards; at this point dipping below the level of the excavation. This thin band of limestone, 1 foot 4 inches thick, differed little from that in the glen. The shale attached both to its upper and lower surfaces was a mass of crushed organic remains, and yielded some good cabinet specimens. The purer limestone of the band itself was not rich in the number

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of its fossils, though it held a few similar to those got in the attached shales. The principal shell remains found both in the limestone and shales were as follows:—a variety of *Productus longispinus*, Sow., which was abundant, and continued so in the overlying shales and thin limestone bands throughout the cutting; *Productus scabriculus*, Mart., was rare; two specimens of *Productus plicatilis*, Mart., were found in the cutting, thus adding others to the single specimen of this shell described in my former paper as found in the same band in Kerrsland glen. A few specimens of *Cardiomorpha oblonga*, Sow., were found in the limestone, and *Cypricardia rhombea*, Phill., was not rare in the overlying shale. In the shales below and above the limestone band, *Orthis Michelini*, L'Eveille, was abundant, and also a few specimens of *Orthoceras*, but all very fragile.

Shale; Glen section no. 13.—Resting upon the above band of limestone, as found in the cutting, was seen a series of layers of shale 28 feet in thickness, though only about 13 feet thick in the glen. These shales are full of shell remains, but so much crushed that good cabinet specimens are rather rare. Their lower part is calcareous and rich in remains of the above-mentioned shells. In addition to them, *Spirifera trigonalis*, Mart., *Rhynchonella pugnus*, Phill., and *Reticularia (Spirifera) lineata*, Mart., were found; *Nucula gibbosa*, Flem., was abundant, along with *Nuculina (Leda) oblonga*, M'Coy; and *Schizodus (Axinus) deltoideus*, Phill., was plentiful, and continued so in all the fossiliferous strata throughout the cutting. A few Gasteropods were also found, *Macrochilina (Macrocheilus) acutus*, Sow., being most abundant. About the middle of these shales they become almost unfossiliferous for a few feet and more clayey in character; but again turn calcareous, until they are capped by another band of limestone, which is very fossiliferous. In the upper portion some of the bands are made up of crushed shell remains. Of these *Leptodomus costellatus*, M'Coy, is prominently abundant, being also found in the shale above the band of limestone presently to be described. A large number of fine specimens of this shell were found in the cutting, some of larger size than obtained elsewhere.

Limestone no. 2; Glen section no. 14.—This limestone was 2½ feet thick in the cutting, being about 2 inches less in the glen. The limestone itself is not rich in organic remains, excepting the stems of a small Crinoid, which, in a large measure, make up its

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bulk. In a thin bed of calcareous shale, upon which this limestone rests, fossils are abundant; some parts being one mass of a small Gasteropod, *Loxonema curvilinea*, Phill. The shells found in the shale below, and noticed above, are abundant. In addition to these, *Naticopsis canaliculata*, M'Coy, and *Natiria (Naticopsis) lirata*, Phill., were found, but not abundantly. A few specimens of *Ptychomphalus (Pleurotomaria) monilifera*, Phill., and one specimen of *Agnesia (Pleurotomaria) contraria*, de Kon., were got. *Entalis (Dentalium) inornatum*, M'Coy, was abundant, and *E. priscum* (?) Goldf., was common, but very fragile. This species was of large size, some specimens being 4 inches in length and many of them 3 inches long, though entire specimens could not be procured, from the indurated character of the shale and fragile nature of the shell. In this shale and in all the shales in the cutting, *Bucania (Bellerophon) decussata*, Flem., and *Euphemus (Bellerophon) Urei*, Flem. were in abundance; and associated with them was a small Lamellibranch, *Nucula lineata*, Phill., rather abundant, but confined to this shale alone so far as my observation went.

As already mentioned, the bed of limestone was poor in shell remains. The calcareous shale that rested upon it contained the same species as the shale below it, and in general held them in the same rich proportions; except the above-named *Nucula lineata* and *Loxonema curvilinea*, which were not found in the shale above the limestone band.

Shales; Glen section nos. 15 and 16.—These shales, resting upon the limestone here described, have a combined thickness of 20 feet. For about 12 feet above the limestone they are slightly calcareous, and rich in organic remains. Above this they become carbonaceous and unfossiliferous. In the lower part shells are found similar to those already mentioned, and generally in bands, some of which are very rich in examples of *Leptodomus costellatus*, M'Coy. In addition to the fossils mentioned, the following genera and species of Ostracoda were common in most of the fossiliferous shales in the cutting, being also found in all the fossiliferous bands in the ironstone measures in this locality:—they were, *Cythere* (?) *Bairdioides*, J. and K., *Beyrichia subarcuata*, J. and K., and *Leperditia Youngiana*, J. and K. While the limestones and their associated shales were rich in shell remains, they were very poor in those of Fish. A fragment of a tooth of *Cladodus mirabilis*, Ag., and one

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tooth of *Petalodus Hastingsiæ*, Owen; a small tooth of *Helodus didymus*, Ag., with a few single scales of *Megalichthys Hibberti* (?) Ag., were all that came under my observation.

Sandstone.—These shales were capped by a thin bed of hard sandstone, 3½ feet thick in the cutting, and 4 feet 3 inches in the glen. It held a few fragments of *Stigmaria*, but otherwise was unfossiliferous. Above this lay a few feet of sandy shale, unfossiliferous except that it held a few vegetable markings too obscure for identification.

Limestone no. 3; Glen section no. 19.—This limestone is 3 feet thick in the cutting, and 5 inches less in the glen. It lies about 6 fathoms below the main clay ironstone, and is found extending throughout the district. It is rich in shell remains, though it produces few specimens fitted for the cabinet. It has a peculiarity of character unique in the locality, and this holds good wherever it is found. Like other thin bands in the ironstone measures, it is not a good carbonate of lime, being little better than a calcareous shale; and the shells that it holds are all broken into fragments. It has the appearance of having been highly crushed while in a soft state, the broken fragments of shells being mixed and pressed together in a confused manner, which gives it a curious flecked and baked-like appearance. It is very rare to find even a single valve quite perfect, and it will thus be seen that good specimens cannot be expected. However, from the larger pieces of the broken shells, they appear to belong to the same genera and species as those found in the lower bands of limestone and shales in the cutting, which are described above. I did not get this band so closely examined as I had intended, so that the list appended is not so full as it might have been; but all those which have been identified from it are inserted in the list.

At the point of the cutting where this band dips below the level of the railway, and where the line crosses the Kerrsland glen and Pogree burn, a fault of nearly 50 fathoms occurs, running from a north-east to a south-west direction. It is an upthrow to the west, bringing the strata exposed in the cutting on a level with a sandstone which lies above the Dalry main coal. From here the cutting runs in this sandstone and along a small basin of the Dalry main coal, preserved as an outlier in a hollow by the fault, and which was worked out about fifty years ago. There

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was little palæontologically interesting in the sandstone; a few *Stigmaria* markings were found, and in the sandy shales, interbedded with the finer sandstone, Plant remains were plentiful, though too obscure for identification. *Calamites Suckovii*, Brongn., and *Cordaïtes borassifolia*, Sternb., were common, particularly the latter, and were the best preserved of the plant remains.

After crossing the road from Beith to Dalry, the cutting runs through a few beds of flaggy sandstones and shales which crop up from under the above sandstone. These rise to the east, or in the same direction that the cutting runs. About 200 yards east of the road the cutting is continued in surface beds, and soon runs out. Nothing of interest was found in this end; the large fault that crosses it, at the point where it intersects the Pogree burn, bringing the fossiliferous strata to a close. The few vegetable remains in the shales and flaggy sandstones, were too obscure for correct identification.

In conclusion, I may state that while the list of fossils here appended contains all that came under my own observation, it is not to be accepted as a complete list of all that the fossiliferous strata hold. From what was noticed, under better preservation a number of genera and species might have been added, especially to the list of Pectens. The specimens of this class were, mostly, so crushed and mutilated that nothing could be done with them.

I have again to thank my friend Mr. John Young, F.G.S., for his kind assistance in identifying and naming all fossils which I felt uncertain about.

On the following pages will be found the list of the fossils above referred to, their occurrence being grouped under three divisions —No. 1, those from the limestone and shale in Gurdy cutting, corresponding to the beds Nos. 11 to 13 in Kerrsland glen; No. 2, those from the limestone and shale in the cutting, corresponding to Nos. 14 to 16 in Kerrsland glen; and No. 3, those from the limestone and shale in the cutting, corresponding to Nos. 19 and 20 in Kerrsland glen.

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LIST OF FOSSILS IN GURDY CUTTING, KILBIRNIE BRANCH, LANARKSHIRE AND AYRSHIRE RAILWAY.	No. 1 Limestone and Shale in cutting; nos. 11 to 13, Kerrsland glen.	No. 2 Limestone and Shale in cutting; nos. 14 to 16, Kerrsland glen.	No. 3 Limestone and Shale in cutting; nos. 19 and 20 Kerrsland glen.
ACTINOZOA.			
Tabulipora (*Stenopora*) *Urei*, Flem.	x	x	x
Zaphrentis cylindrica (?), Scouler.		x	
ECHINODERMATA (CRINOIDEA).			
Platycrinus levis, Miller.		x	x
Poteriocrinus crassus, Miller.	x	x	x
Rhodocrinus uniarticulatus, de Kon.		x	
ANNELIDA.			
Serpulites carbonarius, M'Coy.		x	
Spirorbis Armstrongi, Etheridge.		x	
CRUSTACEA (OSTRACODA).			
Cythere (?) *Bairdioides*, J. and K.	x	x	x
Beyrichia subarcuata, J. and K.		x	
Leperditia Youngiana, J. and K.	x	x	x
POLYZOA.			
Fenestella plebeia, M'Coy.	x	x	
Polypora dendroides, M'Coy.		x	x
BRACHIOPODA.			
Athyris ambigua, Sow.	x	x	x
,, *planosulcata*, Phill.		x	
Discina nitida, Phill.	x	x	x
Lingula mytiloides, Sow.	x	x	x
Orthis Michelini, L'Eveille.	x	x	x
Productus longispinus, Sow.		x	
,, *var.* (?).	x	x	x
,, *plicatilis*, Mart.	x		
,, *scabriculus*, Mart.		x	
,, *semireticulatus*, Sow., *var.* Mart.		x	
,, *Youngianus*, Davidson.		x	
Rhynconella pugnus, Phill.	x		
Spirifera trigonalis, Martin.	x	x	
Martinia (*Spirifera*) *Urei*, Flem.		x	
Reticularia ,, *lineata*, Martin.		x	
Dielasma (*Terebratula*), *vesicularis*, de Kon.		x	

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LIST OF FOSSILS IN GURDY CUTTING, KILBIRNIE BRANCH, LANARKSHIRE AND AYRSHIRE RAILWAY—(*Contd.*)	No. 1 Limestone and Shale in cutting; nos. 11 to 13, Kerrsland glen.	No. 2 Limestone and Shale in cutting; nos. 14 to 16, Kerrsland glen.	No. 3 Limestone and Shale in cutting; nos. 19 and 20, Kerrsland glen.
LAMELLIBRANCHIATA (MONOMYARIA).			
Aviculopecten calatus, M'Coy.		x	
,, *concentrico-striatus*, M'Coy.	x	x	
,, *interstitialis*, Phill.	x	x	x
,, *orbiculatus*, M'Coy.		x	
Entolium (*Pecten*) *Sowerbii*, M'Coy.	x	x	
LAMELLIBRANCHIATA (DIMYARIA).			
Arca Lacordaireana, de Kon.	x	x	
Schizodus (*Axinus*) *carbonarius*, Portl.	x	x	
,, ,, *deltoideus*, Phill.	x	x	x
,, ,, *centralis*, M'Coy.	x	x	
Cardiomorpha oblonga, Sow.	x	x	
Cypricardia striato-lamellosa, de Kon.	x	x	x
,, *rhombea*, Phill.	x	x	
Edmondia oblonga, M'Coy.	x	x	
Leptodomus costellatus, M'Coy.	x	x	
Nuculina (*Leda*) *oblonga*, M'Coy.	x	x	x
,, ,, *attenuata*, Flem.	x	x	
Nucula gibbosa, Flem.	x	x	x
,, *lineata*, Phill.		x	
GASTEROPODA.			
Entalis (*Dentalium*) *inornatum*, M'Coy.	x	x	x
,, ,, *priscum*, Goldf.	x	x	
Polyphemopsis (*Eulima*) *Phillipsiana*, de Kon.		x	
Loxonema Lefebvrei, L'Eveille.	x	x	
,, *curvilinea*, Phill.	x	x	
Macrochilina (*Macrocheilus*) *acutus*, M'Coy.	x	x	x
,, ,, *fusiformis*, Sow.		x	
,, ,, *Michotianus*, de Kon.	x	x	
Naticopsis variata, Phill.	x	x	
,, *canaliculata*, M'Coy.	x	x	
Natiria (*Naticopsis*) *lirata*, Phill.		x	
Tychonia (*Naticopsis*) *Omaliana*, de Kon.		x	
Aclisina (*Murchisonia*) *quadricarinata*, M'Coy.		x	x
Agnesia (*Pleurotomaria*) *contraria*, de Kon.	x	x	
Ptychomphalus ,, *monilifera*, Phill.	x	x	
HETEROPODA.			
Bucania (*Bellerophon*) *decussata*, Flem.	x	x	x

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LIST OF FOSSILS IN GURDY CUTTING, KILBIRNIE BRANCH, LANARKSHIRE AND AYRSHIRE RAILWAY—(*Contd.*)	No. 1 Limestone and Shale in cutting; nos. 11 to 13, Kerrsland glen.	No. 2 Limestone and Shale in cutting; nos. 14 to 18, Kerrsland glen.	No. 3 Limestone and Shale in cutting; nos. 19 and 20, Kerrsland glen.
HETEROPODA—*Continued.*			
Waagenella (*Bellerophon*) *Dumontii*, D'Orb. (?)		x	
Euphemus ,, *Urei*, Flem.	x	x	x
CEPHALOPODA.			
Orthoceras attenuatum, Flem.	x	x	
,, *undatum*, Flem.		x	
,, *cylindraceum*, Phill.	x	x	
,, *Goldfussianum*, de Kon.	x	x	x
Nautilus (*Discites*) *quadratus*, Flem.		x	
Poterioceras (?)		x	
PISCES.			
Cladodus mirabilis, Ag.	x		
Tomodus convexus, Ag.	x	x	
Helodus didymus, Ag.	x	x	
Petalodus Hastingsiæ, Owen.		x	
Megalichthys Hibberti, Ag.	x	x	x

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No. IV.—On New Localities for Zeolites. By Professor M. Forster Heddle, M.D., F.R.S.E.

[Read 10th April, 1890.]

In those countries where minerals are either raised in mines along with metallic ores, or are themselves ores of metals, there should be no difficulty in fixing the locality which furnished them; and any intentional deception connected therewith cannot be but short-lived.

Where, however, they are obtained by search at escarpments or shattered cliffs, or laid bare in quarries opened for dyking or building purposes, there is every opportunity for concealment and deception at the time of the find, and a very great probability of the locality passing out of mind, either from the death of the original finder, or from the surface-weathering, if not the filling up, of the quarry.

In the "Manual of Mineralogy" of Messrs. Greg and Lettsom, the following species are stated to have been obtained from the Campsie Hills, in Stirlingshire:—natrolite, stilbite, heulandite, laumontite, analcime, harmotome, weissigite, prehnite, thomsonite, mesotype.

The statements regarding certain of these species are precise, even to the giving the dimensions of the crystals; while an exact locality—Fintry—is also sometimes specified.

For reasons immediately to be mentioned, the present writer—in revising in 1858 the proof sheets of the above-mentioned work—was desirous of attaching a mark of doubt in connection with this locality, in most if not in all of these cases; but Mr. Greg, finding the locality given in the catalogue of the specimens in the Allan Collection, decided to let the references stand unquestioned.

My doubts arose from three causes. The first was that I found that it was the practice of three peripatetic mineral dealers, who for some years visited Scotland, systematically to mislead their customers as to the localities of all home-found minerals. Two of the tracts of country to which purchasers were directed—on account of their great extent very far from happy hunting-grounds—were the Campsie Hills, and Dumbarton Moor.

So absolutely was this habit recognised as a principle of "business," that the writer was told by one of the above persons

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that his business was "to sell, and not to tell." Even *purchased* information was found to be worthless.

The second cause was that several excursions made by myself among the Campsie Hills proved absolutely without result.

The third, however, had very much the greatest influence.

About the year 1849 I had the pleasure of making the acquaintance of Dr. Thomas Brown of Lanfine, Ayrshire, then in about his seventy-seventh year. Dr. Brown had then far and away the largest collection of minerals in Scotland; he was the contemporary of Macculloch, Thomas Allan, Fergusson of Raith, Sir Charles Gescikie, Thomas Thomson, and Robert Jamieson;—that coterie which was the parent of British mineralogy.

Dr. Brown, living in the district, had kept an eye upon everything that came in his way, and he had collected with his own hands.

One of the queries which I put to him, and that with some frequency, was as to the occurrence of the red stilbite, and red heulandite, in Campsie Fells,—as asserted by the dealers.

Dr. Brown assured me that he knew of no mineral locality in the Campsie Hills; and he stated that in the south-west of Scotland there was but one locality for the above two minerals. This was a quarry-hole opened in the avenue to Cochno House, Dumbartonshire, which quarry was, shortly after the metalling of the avenue, closed up by order of the proprietor—he being annoyed at the number of "vagrom" men who came about the place for bits of the red stones.

Shortly after this time a poor specimen of red stilbite was found by the writer at the Long Craig above Dumbarton; and, as the *red* variety of these two minerals is considered generally to be highly striking, and as such are perhaps the most showy minerals found in Scotland, I have made repeated search, both over the bleak and wearisome stretches of the Campsie Hills, and over the bleak and black and blasted elevated flat termed Dumbarton Moor. With a special view to these two red varieties, about a week was spent at Fintry, a few years ago. As regards the Campsie Hills, the results have been on every occasion a perfect blank. The writer can say that for 40 years not a mineral specimen (aside of jaspers and selenite) has come from these hills, while it is significant that during one or other of his visits to Bowling quarry (extending over a period of five-and-forty years) he has, *with the*

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exception of these red varieties, found every one of the minerals which used to be assigned to the two above-mentioned tracts.

This finding is made more absolute by this—that Mr. John Young, F.G.S., of Glasgow University, who knows this district infinitely better than any one else, has frequently assured the writer that he never heard of any good mineral localities in the Campsie Hills proper; or at least of *zeolitic* localities.

But the lava-streams which form this elevated ridge are continued eastward to Stirling; and the stretch which lies eastward of the Fintry valley is not much smaller in extent than the western portion.

This eastern portion goes under the local names of the Boquhan, Gargunnock, or Touchadam Hills.

In the new "Statistical Account of Scotland," it is stated that some fine specimens of zeolite had been found from time to time on the hill to the north of Fintry.

The writer could find none on Stronend.

In the gap termed "The Double Crags" he found druses which contained only rosette crystals of dark saponite *(prasilite)* in calcite; in the banks of the Endrick small druses of saponite with natrolite; and on the southern slopes of Balhannan Hills, above the Walton reservoir, red heulandite in minute crystals.

There is no record anywhere as regards any other part of these hills; any new observation is thus *a new find*, and if it relates to the two red minerals, an important find.

Mr. Robert Kidston, F.G.S., of Stirling, and Colonel Stirling of Gargunnock, have hit upon three localities which yielded the red mineral or minerals, and one at least of these localities is very promising.

The specimens from the several finds were sent to the writer to name. Mr. Kidston wishes the localities to be recorded, but in refusing to allow his name to stand at the head of this notice, he declines to accept of any share of credit for that whereof the credit belongs to himself alone.

The first of these localities is on the north side of these hills. It was a loose block which lay at the height of 750 feet upon the west side of a spur of the Black Craig, near the head-waters of the Leckie burn. Mr. Kidston is satisfied that it was not a travelled block, but had simply fallen out of the cliff above.

The specimen consists of red stilbite in crystals which interlace

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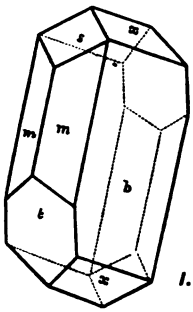
with one another. These crystals are from 2 to 3 inches in length. They lie upon zeolitic or radiating quartz. The interest of the specimen lies in this quartz. The zeolitic quartz associated with red stilbite elsewhere—wherever that is—is white, being, however, frequently rendered pinkish by interstitial radiating plumose natrolite. The quartz here is indigo-blue in tint.

The second locality is the cutting made for a dam embankment for a new reservoir in the Touch Hills near Stirling.

Here red stilbite of two varieties was found. The first is a druse lined with well-formed crystals of about $\frac{5}{8}$ of an inch in length, *a b r p*. The specimen is rather weathered, but fresh ones would be as good as any of the same dimensions got in the west of the country. The other variety is in large sheafy crystals like the specimen from Black Craig; but along with it there are minute crystals of red heulandite of the form drawn (Fig. 1), and rosette crystals of green saponite.



1.

The third locality is at Earlsburn reservoir, in Touchadam Moor. Like the last, the specimens here were got unfortunately just after the reservoir had been completed, and the greater part, and the best, had been carried off.

A box full of specimens was sent from this place. Though the condition of these was very unsatisfactory, yet there was not a specimen which did not give some information bearing upon zeolitic formation; and the interest was all the greater that the inferences to be drawn therefrom were different from, though perhaps not discordant with, those which present themselves at other zeolite-yielding localities.

The subject cannot be more than referred to here.

The rock is an amygdaloidal porphyrite, with pea- and bean-sized druses of all shapes. Many of these are filled with saponite, of a nearly white colour. Most of the crystals are labradorite, but there is a suspicion of sanadine also. While the crystals near to the surface of the specimens are altogether kaolinised, *many of those which are quite close to the margins of the larger druses are remarkably lustrous.* They thus seem *unchanged;* unless this

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high lustre is the first stage in decay, as it often is in exposed crystals.

Some druses are totally filled by a radiating flesh-coloured mineral, which has assumed a solid appearance. This mineral may be natrolite. It is a little like lehuntite, but is more solid. I prefer to say I do not know it.

Brown göthite lines the cavities like a skin, about $\frac{1}{8}$ of an inch thick; over this there is sometimes analcime, sometimes harmotome; and over these milk-white quartz. Occasionally göthite, as rubinglimmer, is superimposed upon either the harmotome or the quartz.

In the larger cavities there are crystals of analcime over $\frac{1}{2}$ an inch in size, *n* and *u a*, covered by white quartz.

One specimen had a crystal of harmotome *a b p*, which was a *simple crystal*, with not a trace of striation upon *b*. This is the only simple crystal I ever saw of the mineral. But the specimen carried abundance of twin crystals, near the form of fig. 6 in Greg and Lettsom's "Mineralogy," differing only in having a narrow re-entering angle, and no face *s*. These are all striated on *b*.

In the larger crystals of analcime their centres are "cluthalite;" but there are specimens with small crystals which are deep red throughout.

The chief interest connected with this find of Mr. Kidston's relates to some minute crystals which lie in a cavity of a specimen which carries analcime and harmotome. These crystals are not $\frac{1}{4}$ of an inch in length—generally not half that size. In colour, lustre, and transparency, they resemble analcime; they are somewhat more lustrous, however, than the analcime here present, both on the surface of their planes and on the fracture.

Their form I am only able to speak to from one or two minute crystals which were shaken off the specimen during carriage. That form is inexplicable.

At first sight they look like pseudomorphs after "dog tooth" calcite. Closer observation shows them to be acute four-sided pyramids. Such pyramids as might be formed by the two lower medial front-, and the corresponding lower medial back-faces of the summit half of an icositetrahedron.

The employment of a powerful lens discloses that, instead of this being merely a distorted crystal of analcime,—distorted through the two pairs of lateral faces of the icositetrahedron being reduced

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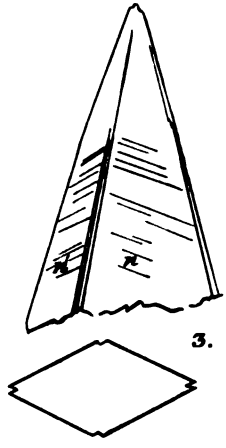
to mere linear dimensions,—a re-entering angle runs up the side, at the acute edge of the four-sided pyramid; and a re-entering angle of extreme minuteness also runs up at the obtuse angle.

A rough sketch is here given. The angle *n n'* seems greater, if anything, than that of the icositetrahedron. These faces are faintly striated. There seems to be a second slightly more acute face surmounting *n*. The flash comes upon *n* of the back half of the twin, at the re-entering angle at the side, almost simultaneously with that from the front half (Fig. 3).



3.

In the *section* drawn, the size of the re-entering angles is much exaggerated.

The appearance is more that of inter-penetrating crystals than of true twins; indeed twins of such a description would be difficult to explain. These crystals were only seen upon one specimen. While there is no mineral more subject to distortion than analcime, such a distortion, or building together of crystals, would seem to defy explanation.

The summits are generally fractured. Occasionally a small crystal with the ordinary obtuse angles seems perched upon the summit of one of these marlinspike-like crystals.

The complexity of composition of analcime in no way *theoretically* entitles it to aspire to the perfect symmetry of the monometric system,—which would seem to pertain to a certain class of elements, and to binary compounds.

The microscope also discloses that it has a molecular structure which approaches in complexity to that of leucite, and that it must find its place among the *tesselites*.

The law of the arrangement of the diversely refracting parts is not in analcime *definite*, as in apophyllite, &c., and possibly the above strange form may aid in disclosing whether there is in its case any law.

Cavities of pre-existent baryte are seen in the specimens which carry the harmotome. I have elsewhere observed this, as well as in those specimens which carry edingtonite. Indeed I have speci-

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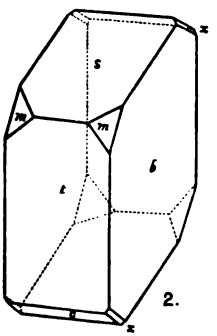
mens in which the baryte is only partly decomposed or removed. This seems to show that baryte was at least one of the substances which by decomposition yielded the two barytic zeolites.

But what has become of the sulphur *here?* In one of the previously observed cases, blende was present; in the other, galena and greenockite were associates. If this locality is opened up, some sulphide will probably be found.

Analcime in a massive form fills rents in this rock.

Crystals of laumontite, over 1 inch by $\frac{1}{4}$ of an inch in width, *underlie* analcime in some specimens.

One specimen carried white stilbite *a b r p*, cluthalite *n*, laumontite, chabasite *r*, and trihedral quartz.



Flesh-coloured lustrous natrolite occurs in fair specimens.

Red heulandite *per se* in small crystals *s t b m p x* (Fig. 2), occurs in small druses, being very rarely overlaid by brilliant colourless crystals, *s t b m p*.

There is one fine specimen of large sheafy red stilbite, with small, and with one large crystal of red heulandite.

The crystals of red heulandite are figured, to show the extreme difference in the development of their faces, although the localities are not four miles apart—although the containing rock is the same—and although the associates are the same, or much the same.

Whether we are to assign this difference of habit in the crystals to difference of size of the druses which contain them, or to difference of depth in the crust—entailing difference of pressure, my ignorance of the localities does not entitle me to suggest. Or whether it may be due to a difference in the rapidity of supply of solidifying material—labradorite having possibly been decomposed in one case, and anorthite in another. The time has certainly arrived when much fuller chronicles must be kept of the paragenesis of minerals—their *associates* in all cases—and, above all, the *sequential order* of their deposition in cavities.

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Such chronicles we must have before we can hope to explain ever varying and extreme changes in crystalline habit ;—and what is even more inexplicable—the association of extreme varieties in one and the same cavity.

There can be no question that if this locality were properly opened up, it would yield a rich harvest. Possibly similar works in the Campsie group may have supplied some of the older specimens; the heavy embanking at the Walton reservoir may have been the source of those assigned to Fintry. The three finds at this east end of the chain of hills show that once the eye is educated to accurate research in some one domain of science, it is capable of doing good work with little effort in another.

No. V.—On Some *Estherie* and *Estheria*-like Shells from the Carboniferous Shales of Western Scotland. By Professor T. Rupert Jones, F.R.S., F.G.S., *Honorary Member*. With a Plate [No. V.]

[Read 13th March, 1890.]

Some years ago my friend Mr. John Young, F.G.S., drew my attention to some *Estheria*-like shells from the neighbourhood of Glasgow, and one of them in particular seemed to me at the time to present features sufficiently characteristic to allow of its being referred to that genus of bivalved crustacea. Since then both Mr. Young and myself have examined it and its associates again and again; and I have come to the conclusion that its form is that of a *Posidonomya*, and that its punctate ornament can be matched among Molluscan shells. Hence it has to be removed from the Crustacean genus, and is treated of further on at page 83 as *Posidonomya punctatella*, Jones.

Among the Carboniferous specimens, however, that have come under our notice are other little *Estheria*-like fossils, and of these I offer the following descriptions, with figures very carefully executed by Mr. George West, who illustrated my "Monograph of Fossil *Estheriæ*," Palæontographical Society, 1863. The plate has been drawn with aid of a grant from the British Association for the illustration of Palæozoic Phyllopoda.

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1. Estheria Youngii, *sp. nov.*
(Plate V., figs. 1*a*, 1*b*.)

This well-preserved right valve, retaining its outline and nearly full convexity, is sub-triangularly ovate, being straight above on the back or hinge-line, elliptically and obliquely curved below, obliquely rounded in front, and contracted and somewhat obliquely truncate behind. It is 8·5 mm. long, 4·5 mm. broad at its greatest height—that is below the umbo, and at one-fifth of the length of the valve from the extreme front margin—and only 2·5 mm. high or broad at the posterior margin.

Below the umbo, which is bare, having been damaged, there are still present ten strong concentric ridges, with wide interspaces, curving neatly in front, and turned up sharply behind, all being parallel with the free (ventral and posterior) margins. The intercostal spaces are marked with obscure and very faint longitudinal striæ (not shown in the figures), also with a scarcely-distinguishable minute punctation, seemingly arranged at one spot in vertical rows. (Fig. 1*b*.) The inside of a similar valve shows numerous longitudinal striæ much more plainly.

The chitinous aspect of the valves, the sharp concentric ridges and their broad flat interspaces, even without the obscure punctation, are characteristic of an *Estheria*. Other specimens, less perfect, occur on the face of the small piece of shale; and some less definite fragments of valves on the other face, together with some valves more circular in shape, of about the same size, and punctate (fig. 7), formerly described as *Estheria punctatella*. All these are non-calcareous.

A very small *Anthracomya* (3 × 1 mm.) very similar in shape to *Naiadites angulatus*, Dawson ("Acadian Geology," 1878, pp. 204, 205, fig. 46), and calcareous, lies close to the figured specimen (fig. 1*a*).

This shale is from the Upper Limestone series of the Carboniferous Limestone, and lies below the limestone at the Arden limestone quarry near Thornliebank, four miles south-west of Glasgow. (See "Catalogue of the Western Scottish Fossils," &c., 1876, p. 91.)

2. Estheria tessellata, *sp. nov.*
(Plate V., figs. 2, 3, 4*a*, 4*b*.)

In the British Museum is a small slab of cannel-coal labelled

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"Ayrshire (?)"* bearing a great number of small delicate valves (mostly double) of what seems to be an *Estheria*, lying close together on the surface. These are now represented by thin, light-brown, earthy, non-calcareous films.

In shape they vary much, apparently from the effects of pressure. The umbo is almost mid-dorsal, whether the valve has been elongated (fig. 4*a*) or not (fig. 2); the latter probably approximates more nearly to the normal shape, with the umbo rather forward, and the elliptically sub-oval valve measuring diagonally about 7 mm. in length, and about 4½ mm. high. The dorsal edge or hinge-line is about 4 mm. long in each case.

The numerous, exquisitely delicate, concentric striæ on the surface have between them minute quadrate pits, defined by short vertical lines joining the long striæ at regular intervals (fig. 4*b*), and thus forming a decussated and tesselated pattern. This has the effect of giving a slight radiate appearance to some parts of the valve under the microscope. There are also coarser radial lines, which have been produced by pressure on the originally convex valves.

Among the specimens there are to be seen some edge-views (like fig. 3) of the bivalved carapace filled with matrix, about 3½ mm. wide, and 6½ mm. high. This relative height (if the valves have not been disarranged by pressure) goes to show that fig. 2 does not give the full height of the valves of this species. The figures of *Anthracomya lævis*,† Dawson, have some resemblance to figs. 2 and 4, but the striation is too coarse, and the umbo too near to one end of the hinge-line.

With regard to the minute sculpturing of the surface, Dr. Goldenberg figures a somewhat similar ornament for his *Estheria limbata* ("Fauna Saræpontana fossilis," Heft 2, 1877, plate ii., figs. 12-14, p. 43), and still closer for his *E. rimosa* (*loc. cit.*, figs. 16-18). The dorsal line in our figures 2 and 4 is much too straight, however, for *E. rimosa*. Dr. Baird has figured an analogous ornament, but consisting of little round pits, closely limited by longitudinal and cross lines, in the lowest (newest) part of the edge of

* It is probably from the Upper Coal-measures of Ayrshire, and similar to a cannel in the Upper Coal-measures at Airdrie, Lanarkshire.

† Salter, *Quart. Journ. Geol. Soc.*, vol. xix., 1863, pp. 79-80, fig. 2; and Dawson, "Acadian Geology," Suppl., 1862, and 3rd ed., 1878, p. 204, fig. 44.

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the valve of *E. Jonesii*, *Proc. Zool. Soc.*, 1862, plate xv., fig. 1*d*. The ornamentation, though microscopic, has suggested the specific name *tessellata*.

The ornament on *Chione Californiensis* and *Lucina Sowerbii* is somewhat of the same pattern.

3. Estheria tegulata, *sp. nov.*
(Plate V., figs. 5, 6*a*, 6*b*.)

Scattered on or near a bed-plane in a piece of cannel-coal in Mr. John Young's collection, and probably from the Upper Coal-measures at Airdrie, Lanarkshire,* are many delicate small valves of what appear to belong to *Estheria*. They occur as thin, light-brown, earthy, non-calcareous films, leaving a glossy black surface when removed.

Some are elongate and sub-oblong (fig. 6*a*); others are shorter and more triangular. The umbo in each case is (or has been) at the anterior angle, as indicated by the position of the concentric striæ, which are very thin and numerous. The dorsal line is straight and about 3 mm. long in fig. 5; in fig. 6*a* it is longer and not quite straight, but depressed (perhaps by pressure) in the middle.

These are smaller than the valves of *E. tessellata*, figs. 2-4); but, being magnified much more, they look larger on the plate. As with those valves it may be that pressure has altered the shapes by elongating some very much (figs. 4*a* and 6*a*), whilst others almost retain their original form (figs. 2 and 5). Besides the shape of these better-preserved valves, the relative position of the umbo is very distinctive of the two species; and the minute sculpturing of the surface (shown in figure 6*b*) is another and peculiar feature of difference. Here the striæ, raised lines, or concentric edges of the successive layers of the shell appear to be neatly notated with numerous parallel short incisions (as it were), leaving so many squarish, tile-like portions of each edge to overlap the next little concentric furrow between the striæ.† Hence the proposed appellation *tegulata* (tiled).

* "Catalogue of the Western Scottish Fossils," 1876, p. 65.

† A similar ornament is figured in Dawson's "Acadian Geology," 1878, p. 302, fig. 102*c*, as belonging to *Microdon Hardingi*, Dawson, a molluscan shell (1¼-inch long) allied to *Arca*, and characteristic of the upper part of the Lower Carboniferous Limestone at Windsor, Nova-Scotia.

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This ornament is associated with, and indeed gives rise to, a delicate set of radial lines (under the microscope), distinct from the radiating cracks. Thinking that this radiate appearance was the same as that noted by Dr. E. Weiss in his genus *Estheriella*, I referred to the specimens under notice as belonging to this genus in the "Seventh Report to the British Association on the Phyllopoda of the Palæozoic Rocks," 1889. Since then Dr. Weiss has very kindly sent to me type-samples of his genus, and I find that the radii are of a quite different character, are fewer, and are confined to the newer part of the valve.

4. Posidonomya punctatella, Jones.

(Plate V., figs. 7*a*, 7*b*.)

Estheria punctatella, Jones. *Geol. Mag.*, vol. ii., 1865, p. 185.

Estheria punctatella, Jones. *Trans. Geol. Soc. Glasgow*,* vol. ii., part 1, 1867, p. 71, plate i., figs. 5 and 5*a*.

This little fossil was first noticed by Mr. John Young, F.G.S., who exhibited specimens to this Society in 1865. (See *The Geol. Magazine*, vol. ii., p. 185.) It was afterwards described and figured in the *Transactions*, *loc. cit.*, but the two figures were not perfectly true. It has now been re-figured in Plate V., figs. 7*a* and 7*b*, and accidental chipping and flaking may account for some of the alteration in its appearance.

As Mr. John Young has already pointed out, similar fossils occur in great profusion in the Carboniferous shales at several localities in the West of Scotland; particularly, for instance, at the Linn-Spout, Dalry, Ayrshire, as well as in some shale at the Arden quarry, near Thornliebank, not far from Glasgow, and about 20 miles from Dalry. This quarry has not been worked for more than twenty years, and specimens are consequently not now to be had. The little specimen, however, here figured, is very much smaller than the others referred to; and it is not calcareous, though thicker and more brittle than the *Estheria Youngii* which occurs with it in the same piece of shale.

The figured specimen measures only 8·3 × 5·5 mm.; but those referred to as occurring also as Thornliebank are 28 × 19 mm., and those from the Linn-Spout, Dalry, vary from 20 × 11 mm. to 32 × 22 mm. All these larger forms from Dalry are moderately

* A note by Mr. John Young, F.G.S., on the occurrence of the strata follows the description of the fossil.

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thick, whitish, and calcareous; and the large specimens from Thornliebank, though thinner by pressure, and more or less coated with a pyritous film, are calcareous also.

Like figure *7a* in general shape, all these larger specimens have also the delicate superficial reticulation and pitting, shown in figure *7b*, over all the concentric wrinkles and furrows of the shell. In some cases this consists of pretty little lozenge-shaped areas close together; in others they are bound by polygonal meshes; and in some they appear to be round. This minute ornament is due most probably to a reticulate structure, which has become filled up and obscured by carbonate of lime. It is apparent only on the surface of the shell.

Excepting from its small size and its being non-calcareous, figure *7a* may well be considered to belong to the same genus and species as the similar but larger forms above noticed. In that case it may be regarded as one of the younger individuals, and may have lost its calcic carbonate, remaining somewhat thick and brittle.

Hence I am induced to ignore my first determination (in 1865) of its relationship, and to relegate it to the Mollusca, more especially as a punctate ornament is not very rare among molluscan shells. *Lepton*, for instance, and *Kellia* have a delicate pitting or minute reticulation all over, not defined by concentric lines. Mr. John Young has noticed a somewhat similar reticulato-punctate surface on some well-preserved shells of *Posidonomya* and *Anthracoptera* of the Scottish Coal-measures, and also those of some other Carboniferous genera, as *Pinna*, *Aviculopecten*, *Pteronites*, *Myalina*, &c., sometimes associated with them.

The shales at Thornliebank and Dalry are on the same geological horizon, Mr. Young informs me, and are associated with the same group of organisms. They belong to the "Upper Carboniferous Limestone series."

The punctate bivalves under notice "exist in thousands, both at Darnley (Thornliebank), and the Linn-Spout (Dalry) in a thin shale, in which they seem to be the only organisms present;* but in the other shales lying close to it, above and below, we find examples of *Pteronites* and *Cypricardia*-like shells, having an estuarine or brackish character about them; and immediately below the lower shale is a seam of coal."—Mr. John Young, F.G.S., *in letter*, July 18, 1887.

* A Polyzoon and a small *Anthracomya* are noticeable as accompanying *Estheria Youngii*. (See above, p. 80.)

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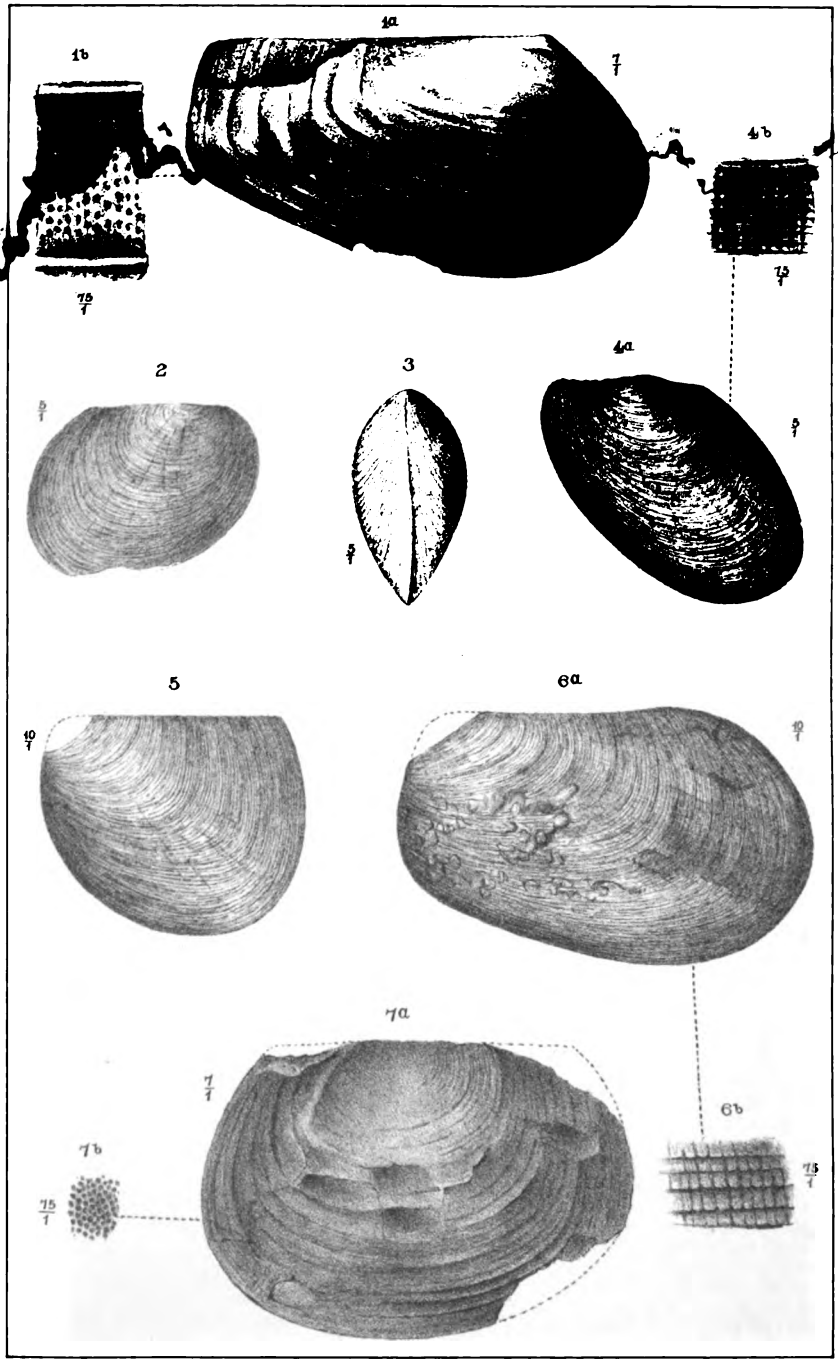

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CARBONIFEROUS ESTHERIÆ &c., SCOTLAND.

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Regarding these bivalves as molluscan, we may perhaps correctly refer them to Bronn's genus *Posidonomya*. This species may be defined as having broadly sub-ovate valves, when young almost equilateral, measuring from about 8·5 × 5·6 mm., with the hinge-line nearly straight, almost as long as the valve, and forming angles with the end margins; umbo in advance of the middle; anterior and ventral margins boldly curved; posterior curve rather less, being somewhat contracted below.

In the adult state the valves measure as much as 32 × 22 mm.; they are more nearly ovate than figure 7*a*; the hinge-line is straight, but is overhung by the umbo at about a third of the length of the valve from the front, and makes a more distinct angle with the posterior than with the front margin. The latter is rounder and fuller than the former; and an oblique ridge has left traces of its presence on the posterior moiety of some of the crushed shells from Dalry. The surface bears numerous concentric ridges or wrinkles, of unequal breadth, and with unequal intervening furrows. The whole is ornamented (when well preserved) with a microscopic reticulation; when perfect the meshes are slightly sunken, and the areas within them slightly convex; but varying from that condition to minute pits, and either lozenge-shaped, polygonal, or nearly round.

My friend Mr. Young has shown me clear evidence that the valves of *Posidonomya Becheri* exhibit the same punctate ornament, due probably to a prismatic structure of the shell, as is visible in the fossil valves from Thornliebank and Dalry. (See figure 7*b*.) The general appearance of these shells is also like that of some of the *Posidonomyæ*, and I have now little or no hesitation in referring them to this genus.

Explanation of the Plate.

Fig. 1.—*Estheria Youngii, sp. nov.* 1*a*, Right valve (×7 diam.); 1*b*, ornament (enlarged × 75 diam.) Arden quarry, Thornliebank; J. Young's collection.

Figs. 2, 3, 4.—*Estheria tessellata, sp. nov.* 2, Right valve, probably of almost the original shape; 3, edge view of a carapace full of matrix; 4*a*, right valve much elongated by pressure (all × 7 diam.); 4*b*, ornament (enlarged × 75 diam.) Cannel-coal, Ayrshire (?); British Museum.

Figs. 5, 6.—*Estheria tegulata, sp. nov.* 5, Left valve, probably of nearly the original size; 6*a*, left valve, elongated by pressure (both magnified 10 diam.); 6*b*, ornament (enlarged × 75 diam.); cannel-coal, Airdrie (?); J. Young's collection.

Fig. 7.—*Posidonomya punctatella*, Jones. Young state; 7a, left valve (×7 diam.); 7*b*, punctate ornament (×75 diam.). Arden quarry, Thornliebank; J. Young's collection.

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No. VI.—On a Peculiar Structure—Spines within Spines—in Carboniferous Species of the Productidæ. By John Young, F.G.S., *V.P.*

[Read 30th May, 1880.]

The purposes for which the external tubular spines on the shells of the Productidæ existed have long been a source of conjecture to those palæontologists who have taken up this group for investigation, but in spite of all that has been written on the subject, we are still ignorant, in a great measure, as to what were their several functions.

As the spines are seen to be very variable, in the different species, both as to length, diameter, and numbers, it is probable that their uses may not have been the same in all cases, and future investigators may be able to show that some of the theories previously held may be correct only as regards certain forms.

In 1876, Mr. Robert Etheridge, jun., F.G.S., read a paper on an adherent form of *Productus* from the Lower Carboniferous Limestone strata of the East of Scotland (*Quart. Journ. Geol. Soc.*, p. 454), which was found attached, chiefly by its spines, to small stems of crinoids, polyzoa, &c. In describing his species—*Productus complectens*—Mr. Etheridge stated the opinions of those palæontologists who had expressed their views as to the functions of the spines, and tabulated their conclusions, as follows:—"The spines were considered—

1. "To be for the passage of tendons of attachment, by von Buch."

2. "To be for the introduction of water into the interior of the shell, by de Verneuil."

3. "To be for simply retaining the shell in position in fine sediment, by d'Orbigny."

4. "To be without essential functions, by Bronn."

5. "To be of unknown function, by Eichwald."

6. "Not to serve as means of attachment to the shell, by de Koninck and de Verneuil."

7. "Not to act as a conduit to the interior of the shell, by de Koninck and Bronn."

More recently, in 1880, our late Honorary Member, Dr. Thomas Davidson, in the Supplement to his "Monograph on the Carboniferous Fossil Brachiopoda," vol. iv., part iii., p. 305, Palæonto-

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graphical Society, expressed his views as to the uses of the spines, and was inclined to consider their functions as having been somewhat varied, in the several species; and that they may be differently explained—some of the spines having been evidently used in some species for the purpose of attaching the shell to foreign bodies, while in others they may have helped to steady the shells on the soft muddy sea-bottoms on which they lived.

The discovery which I have now to record, the occurrence of spines within spines, and which forms the subject of the following remarks, appears to favour the view held by de Verneuil, that the tubular cavity of the spines in certain species served to admit water to the interior of the shell. This discovery, made quite recently, and quite accidentally, was unexpected on my part. I happened at the time to be grinding some sections of Carboniferous polyzoal shale, from Roscobie, Fifeshire, for examination under the microscope. In this shale there were some examples of *Productus scabriculus*, Martin, with the spines still attached and crushed down flat with the shell amongst the polyzoa. In some of the thin, transparent sections then made, several of the spines were cut through at various angles, and I found that near their attachment to the outer surface of the shell, and within the hollow tubes of the spines, many of the tubes were guarded by a barrier of minute spines, projecting inwards towards the centre in a radiating manner around the inner surface, and with their bases planted deeply within the wall of the spine. This I have endeavoured to show in the sketches and sections exhibited. These small spines are also seen, in the sections, to be tubular like those within which they are enclosed, and vary in numbers from a dozen to twenty or more. On the external, frontal surface of many specimens of the shell of *Productus scabriculus*, there are to be seen, in well-preserved examples, two groups of spines of different sizes, but, so far as I have examined them, the small internal spines, above referred to, appear to be present only within the larger spines. In the latter, which are about half a line in external diameter, the tubular cavity varies from one-third to one-half the diameter of the spine, and is now filled with an infiltration of structureless calcite quite distinct from that forming the spine walls themselves, these being formed of an organic calcite, having a dense and fine concentric lamination around the spines, and on their surfaces a silvery but slightly copper-coloured lustre, characteristic of nearly all the spines in the Productidæ.

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When I first discovered this barrier of minute spines within the larger spines of *Productus scabriculus*, I thought the peculiarity might, perhaps, be confined to some single example, or to the before-mentioned locality, but I have since found that it exists in all the specimens of the shell on which the spines are still attached, as well as in those from the strata of other localities within our Scottish coal-fields, although not always in the same fine state of preservation as those found at Roscoble.

In the numerous sections which I have prepared, I find that this peculiar arrangement of minute spines always occurs at the same point within the tubes of the larger spines, and is planted in what may be termed the neck of the spine just outside the surface of the shell, the rest of the tubular cavity outwards being free. In the sections one never sees the whole of the small spines which formed the barrier, as, generally, in both longitudinal, transverse, and oblique sections, more than half of the spines are cut away in the grinding before the section is thin enough to display them. These small spines are quite microscopic in size, and taper toward their points. Many of them project at nearly right angles into the tubular cavity, extending, in some instances, right across it. In other instances it is evident that numbers of them have suffered from erosion, their bases still remaining visible within the walls of the spine. This barrier does not seem to occupy a space within the length of the tubular cavity greater than the seeming diameter of the spine within which it is enclosed.

It will therefore be seen that, in preparing sections, it is only when the spines chance to be cut at the proper point that any traces of the barrier can be looked for. Hence in many cases, when examining sections which at first promise well under the microscope, it is found that most of the spines have been cut either too far away from the point where the barrier existed, or too close to their attachment to the surface of the shell; it is therefore only in chance sections that favourable examples turn up. Few sections ever show more than from twenty to thirty of the smaller spines present, but as they seem to have radiated inwards into the cavity of the spine all round its surface in an inosculating manner, at least double these numbers would probably be present in its perfect condition. Many of the barriers in certain of the species appear, however, to have had far fewer spines than is here noted.

The sketches which I now exhibit illustrate the appearance of

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this barrier, and the number of small spines seen within those of the larger spines that have been cut in longitudinal, transverse, and oblique directions, according to the positions in which they chanced to lie in the shale. The sketches thus show how constant is its occurrence, and its position, in those spines in which it was present, and which have chanced to be cut at the proper points to show it.

Having thus shortly described the appearance of this arrangement of small spines, and its mode of occurrence, I shall not now offer any further opinion as to its functions, beyond what I have already stated, viz., that it seems to favour de Verneuil's view—that the tubular spines conveyed water to the interior of the shell, the barrier thus guarding the passage near the point where the tube entered the inside of the shell, and preventing the entrance of impurities, or minute organisms which might be enemies of the inhabitant. This view seems to be supported by the fact that only in the larger spines with the wider tubes is the barrier seen to exist. In all the species in which it is found the lesser spines appear to have had no barrier, because, probably, their tubular cavities were so small as not to necessitate the existence of such an arrangement, although still wide enough to admit the passage of water.

Since the period when I first discovered the barrier in the spines of *Productus scabriculus*, I have searched for its existence in some of the other species of the same genus, and have lately found it to be present in the larger spines of *P. punctatus*, Martin; *P. longispinus*, Sow.; and *P. semireticulatus*, Martin; but as the spines on the two last-named are few in number compared with those on the former species, I have failed, as yet, in getting as good examples of the barrier as those obtained in *P. scabriculus*.

Probably this barrier existed in the spines of other species of the genus, but owing to the difficulty of finding specimens with the spines still attached to the shell, and lying in a suitable position for being sectioned, it may be difficult to prove its presence in every case. I hope, however, that other examples may yet be found, besides those here noted. So far we do not know much regarding the extreme length to which the spines extended in the several species of Productidæ. Dr. Davidson, in his work above referred to, has carefully figured all the British species of *Productus* which came under his notice as having the spines still attached to the shell, but none of his illustrations show the full

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length which the spines attained, although some of them are seen to have been at least 5 inches long. The original specimens of these I now exhibit. As stated by Dr. Davidson, it is probable that some of them may have been much longer.

The explanation I would here offer, as to the barrier being always found close to the base of the spine, and never further up the tube, is founded on the supposition that it came into existence during the earliest growth of the spine, and therefore close to the shell, the further growth and extension of the spine being not from the base, but by additions to its outer extremity.

In bringing these remarks to a close, I hope that they will lead to a further examination of this new and interesting structure, and thus help to establish more clearly at least one of the supposed functions of these tubular spines, viz., the passage of water to the interior of the shell, a function which is further indicated by the openings of the spines, as pores, on the inner surface of many of the shells.*

* Illustrated in the Supplement to Dr. Davidson's "Carboniferous Brachiopoda," plate xxxvi., figs. 16 and 17.

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No. VII.—The Geology of the Lugton Valley. By James S. M'Lennan.

[Read 13th December, 1888.]

The valley through which the Lugton water flows is situated in the northern part of Ayrshire, with a small portion of its upper end in Renfrewshire, and comprises parts of the parishes of Neilston, Beith, Dunlop, Stewarton, and Kilwinning. It runs S.W., and is 13 miles in length, with an average width of nearly 2 miles. To the E. lie the parallel valleys of the Glazart and the Annick, and on its W. those of the Dusk and the Garnock.

With the exception of a few patches of peat moss, the district is a rich agricultural one, long famous for the excellence of its dairy produce. It contains no towns, and except in the hamlets of Ouplawmoor, Lugton, Burnhouse, Auchentiber, and Toranyard, and the mining villages of Doura, Bensley, and Fergushill, the population is mostly confined to its numerous well-appointed farm steadings. The mansions of Caldwell, Montgreenan, and Eglinton Castle with their surrounding woods and policies give a pleasing variety to the landscape, which is otherwise generally plain and unadorned.

The lowest rock in the valley consists of beds belonging to the upper member of the trappean series which forms the highlands of Renfrewshire, and stretches across its confines into Ayr and Lanark. These are made up of a variety of bedded basalts, melaphyres, and porphyrites, with occasional bands and beds of fine tuff and coarse volcanic agglomerate. Sometimes sandstones, shales, and thin impure limestones are seen. When continuous they are fringed with a border of ash-like strata, upon which rest the lower members of the Carboniferous Limestone series, and which vary much in different localities. At Beith and Caldwell they consist of ashy grits, sandstones and shales, with conglomerates, and seem to have been derived from the tear and wear of the underlying traps and tuffs. Sometimes they contain interbedded tuffs and agglomerates, showing that the volcanic forces were repeatedly active during the formation of the overlying mass.

While these trappean rocks are supposed to underlie the entire basin, they come to the surface only in its N. portion, and for a distance of 4 miles occupy the surface of the valley, except that part covered by Lochlibo, and a patch occupied by the Lower

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Limestone series. Farther down in the parish of Dunlop they form the surface of the E. slope for a farther distance of 3½ miles, occurring twice on the W. side near the farms of Brownhills and Sclehead, both in the parish of Beith. In this first-mentioned locality these porphyrites contain augite and closely resemble dolerite.

On Lochridgehills farm, about a mile S.E. of Lugton station, a fine example of columnar basalt is seen cutting through the bedded felstone rocks—the columns being 5-sided, 6 to 10 feet in height, and 18 to 24 inches in diameter. "Many of them," says Mr. Dugald Bell, "are curiously curved, and the contraction joints between the columns, like those of Cathkin, are filled with vertical veins of calcite mixed with a green serpentinous earth. The basalt is a fine-grained rock, of a blackish-grey colour, and a friend informs us that on pounding it into fine grains he found some of it attracted to the magnet, showing the presence of magnetic iron ore in its composition."

Immediately over these trappean deposits lies the Carboniferous Limestone series, consisting of beds of limestone, shale, and sandstone, with seams of coal and clayband ironstone. A narrow tongue-shaped portion of this formation is situated in the bottom of the valley at its extreme N. end, some 16 acres of its extent being covered by Lochlibo. Near the E. side of this lakelet, beds of white sandstone have been quarried for building purposes, and old shafts are still to be seen where coal was wrought some forty years ago. Tradition says that the loch broke in and flooded one of these pits near its margin, several lives being lost. Half a mile W. of Caldwell house coal was wrought for several years in a pit near the march of the two counties, but being of inferior quality the work ceased about twelve years ago. A short distance below Caldwell station, and close to the railway, clayband ironstone is at present wrought, and at Lugton similar operations were carried on in a pit now filled up. On Waterland farm it is worked at no great depth in the method of early mining days by "ingaun ees."

In connection with this seam of ironstone is found a thin layer containing fine specimens of "Cone-in-cone" or "Maggie band," first figured and described by David Ure in his "History of Rutherglen and East Kilbride," 1793. In volume viii. of our *Transactions* a paper on "Cone-in-cone," by Mr. John Young, F.G.S.,

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with illustrations of specimens from this very layer, gives the most satisfactory explanation of this peculiar structure yet put forward.

The limestone is found along the E. side of the valley for a mile below Lugton station, and, with the exception of the two faults caused by the trap already referred to, it covers the entire W. side for five miles. In two narrow strips at Bentfauld and Clonbeith it crosses the valley still farther down.

At Burock, about a mile N. from Dunlop, a "little outlying basin of the limestone entirely surrounded by the underlying igneous masses" is well seen in a railway cutting. Another detached patch occurs farther E. in the valley of the Annick at Gabrochill. The existence of such remnants shows that the limestone series once covered all this region, and that it was afterwards removed by denudation.

The limestone at Waterland is the main or lower limestone of Beith and Howrat. It is not so well developed in this basin as farther to the W., where it reaches a thickness of 100 feet—its highest development in Ayrshire, or indeed in Scotland. It is of considerable thickness, some 10 or 12 feet, and is intersected by joints or fissures perpendicular to the lines of bedding, which cause the rock to break up into large tabular masses. Its upper surface here presents a brownish appearance caused by a thin layer of volcanic ash, mixed with limey matter, said to overlie a large extent of the limestones in North Ayrshire. It contains numerous species of shells and corals, and remains of fishes, such as teeth, spines, &c., of *Psammodus*, *Helodus*, and *Petalodus*; and *Sigillaria* roots are frequently met with in its upper portion.

About three miles S.W. of Waterland, on Lugtonridge farm, the rock consists of a bed of whitish clay topped by a seam of coal 1 foot, 1½ foot of clayey shales, a post of limestone 3 feet, 1 foot of shale, 5 feet of dark-coloured limestone, nearly 3 feet of drab-coloured shales, surmounted by 1½ feet of vegetable soil.

Of the five limestones which the Survey gives as found in the Dalry basin, the lowest or Howrat limestone has the most extensive area. The Highfield limestone, the next in ascending order, can be seen, says Mr. Robert Craig, "in the Caldwell coal-field, and it crops out on the N.E. of Lochlibo, near Shilford, in the parish of Neilston, being found to the S. of the large fault which runs from Ardrossan up the Dusk and Lugton valleys into Renfrewshire.

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Crossing into Kilwinning it stretches S.E. by Goldcraig, Lyleston, and Clonbeith into the S. of Stewarton parish. It has been extensively wrought in all these places, and is still being mined at Moscow and Cessnock. Some doubts have been expressed as to the limestone of these last-mentioned places being the Highfield bed; but as it is on the same horizon and bears the same physical and fossiliferous characters as the Dalry deposits, it may be regarded as the same until it is proved to be different."

The two highest beds of limestone of the Dalry basin—the lower and upper Linn limestones—extend into the north of Kilwinning parish, and are seen on the Lugton water near the volcanic rocks found there, but much reduced in thickness.

The lower limestone is very rich in fossils, but while the Highfield beds contain few, the shales associated with them are very fossiliferous, and the Linn limestones contain many organic remains. The Survey gives a list of 96 fossils found in the Howrat limestone, and Mr. Craig, in the list attached to his paper "On the Upper Limestones of North Ayrshire,"* gives 96 as found in the Highfield, and 208 in the Linn limestones.

These consist of corals, crinoids, crustaceans, polyzoa, brachiopods, &c., up to fishes, and in the Memoir belonging to the 22nd sheet of the Survey, 77 genera or 182 species are named as being found in the coal basins of North Ayrshire. A good list of the fossils found in the Dalry basin is given by Mr. Robert Craig in vol. iii., part 2, of our *Transactions*.

Of the sandstones and shales included in the upper limestone series several fine sections are exposed on the banks of the Lugton near Montgreenan, where some of the higher members of the sandstone of a soft texture have been used for the manufacture of whetstones.

Above the Carboniferous limestone series, and separating it from the Coal Measures, there is found, in the S.W. of the Dalry basin, a large extent of later erupted volcanic rocks, well developed at Blair and Bankhead, where they form a ridge for some four miles with an average breadth of nearly half a mile. This great sheet of basaltic rock is also met with in the Lugton valley, beginning near Sevenacres Mill, and extending in a narrow strip past Montgreenan House, Old Mains, and Auchenharvie. In the last-named locality it forms the foundation on which the old castle of

* *Transactions*, vol. viii., part 1.

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Auchenharvie stands, besides supplying the materials of which its outer walls are mostly composed.

The rest of the area of this basin is overspread by the Upper Coal Measures, with a breadth of two miles on the W. side, widening out to double that distance, and four on its E. border, being a small portion of the coal-field of North Ayrshire which stretches E. from Saltcoats by Kilwinning, Dreghorn, Kilmarnock, and Hurlford to Galston and Newmilns.

A little below Sevenacres Mill the main coal is seen cropping out on the banks of the Lugton, beautifully columnar by intrusive dolerite. It has the largest area in the district, and is the lowest at present wrought. It is of good quality and 4½ feet in thickness. A tradition runs that it has been worked for two hundred years. Mr. Rodger, the manager at Fergushill, informs me that there is an old pit on the side of the Lugton where the Kilwinning road crosses, and, when some of its old workings were gone through, the workmen found tools and wooden picks shod with iron lying as if left in a hurry, leading to the conclusion that the pit had been drowned out. This is said to have been one of the first pits in Scotland which had a pumping machine driven by water power, the pumps being made of wood hooped with iron. Traces of the dam with the "lade" can still be seen.

About 2½ fathoms above this main seam occurs a coal of very limited extent, from 1 to 3 feet thick. Some 2½ fathoms above this lies the Stone coal, which consists of 6 inches of coal, 10 inches of stone, and 22 inches of bottom coal. This is succeeded about 9 fathoms higher by the Ell coal 2 feet 8 inches thick, with a fireclay pavement. Then 3 fathoms up is found a coal of 1 foot thick, supposed to be the equivalent of the Blackband ironstone of Plan, near Kilmaurs.

The Ladyha' coal, with a thickness of 1½ feet, is met with 5 fathoms higher; and this is the seam chiefly wrought at Doura, supplying the fireclay manufactured there. A seam of oil shale 12 inches thick occurs 4 fathoms above this, and has 12 inches of coal underlying it. A ton of this shale, which contains the remains of fish bones, teeth, and scales, yields from 32 to 36 gallons of crude oil. It has been mined at Doura and is now worked at Annick Lodge.

Some 18 fathoms higher the Wee coal is found 2 feet thick, and 2½ fathoms above this another coal seam, known as the Turf coal,

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3 feet thick, is met with. Above the Turf coal 2½ fathoms lies the Splint or Parrot coal, 3 feet 7 inches thick. The last or highest seam presently wrought at Fergushill is the Five Quarter coal, which is 4½ feet thick and of very limited extent.

Thus there are found in this basin of the Lugton valley no less than 9 seams of coal, with an aggregate thickness of 25 feet 7 inches.

In various parts of this river basin intrusive rocks of post-Carboniferous age are met with. These are supposed to be connected with the doleritic plateaux of Antrim and the Western Isles, of which the Giant's Causeway and Fingal's Cave are well-known portions, and are probably of Miocene age. These intrusives occur in the form of irregular bosses or sheets, and as dykes or veins. A little below Lugton station one of these dykes about 20 feet in breadth crosses the bed of the stream in a W. direction, forming a waterfall of about 5 feet high. Two miles farther south another dyke 60 feet broad strikes N.W. from near the village of Burnhouse through the Barr coal-field to the farm of Craighouse, some half mile S.E. of Beith. Its entire length is 3 miles. Along its N. side it is clearly defined, being in some places high and steep.

Near its end it rises 100 feet above the ground to the N., and at this point stands the castle of Giffen—a tower once 40 feet square, and five storeys high. The greater portion of it fell in 1838, and now only a small fragment of one of its corners remains. It belonged, with the surrounding barony, to a younger branch of the Eglinton family. When visiting this crumbling castle many years ago I noticed that it is in a straight line with Auchenharvie Castle, already referred to, and with Dundonald Castle in Kyle. This last, once a royal residence, and the scene of the death of Robert II., is built on a boss of the very same rock on which Giffen stands.

It is an interesting fact that from very early times such elevated masses of intrusive rock have been selected as sites for strongholds, and that, in Scotland at least, most of our great historic castles have been so placed. Those of Edinburgh, Stirling, Dumbarton, and Dunbar all occupy the summits of commanding heights of this rock, around which the din and strife of human passion have often raged.

I am reminded in this connection of a striking passage in Hugh

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Miller's "Geology of the Bass," wherein he says, "I remember at one time deeming it not a little curious that the early geological history of a country should often seem typical of its subsequent civil history. If a country's geological history had been much disturbed; if the trap rock had broken out from below, and tilted up its strata in a thousand abrupt angles, steep precipices, and yawning chasms, I found the chances as ten to one that there succeeded, when man came upon the scene, a history, scarcely less disturbed, of fierce wars, protracted sieges, and desperate battles. The stormy morning during which merely the angry elements had contended I found succeeded, in almost every instance, by a stormy day maddened by the turmoil of human passion."

Some 3 miles further S., near Auchentiber, there occurs on both sides of the Lugton a ridge of volcanic rock nearly 2 miles in length, which differs from the two last-mentioned in running slightly N.E. For some distance it is parallel to the Lugton, and at its N. end it rises on its W. side some 30 feet above the stream. Hard and compact in some places, in others it is soft, weathering into a dark brown earth which forms an excellent soil. Several of these intrusive dykes are met with in the Fergushill coal-field—the largest stretching in a direction similar to the last.

The Drift series found in this district comprises the Boulder-clays, sands, and gravels forming the Kame series of the Survey. The Boulder-clay covers a large extent, and the lower division is of varying thickness, tough and compact, and, where it overlies the Coal Measures, is of a dark gray or bluish colour. It is full of stones small in size, more or less rounded and well striated, which are mostly of local origin. The underlying rocks are smoothed and striated, as is specially evident over the limestone surfaces, and the striæ show a direction nearly N. and S. I am not aware of any arctic shells or mammalian remains being found in this area, as was the case in the Carmel valley near Kilmaurs, and in Cowden glen a little beyond the N. water-shed of the Lugton. The upper portion of the Boulder-clay is coarser in quality, and not so dense in texture as the lower, and often contains large angular stones. As the district is an agricultural one most of the erratic blocks which once studded its surface have been removed. About half a mile beyond the E. water-shed of the basin, on the farm of Brannelside, in the parish of Dunlop, one of these blocks is still to be found. It is known as "The Thougrit Stane," and is a mass of

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blue augitic porphyry of hard and compact texture. It is oval in form, rises to a ridge-like shape on the top, and measures 12 feet 6 inches long, 4 feet 6 inches above the ground, and 8 feet at its greatest breadth; it probably contains upwards of 800 cubic feet. Some have thought that it was once a Logaustone or rocking stone.

A short distance N.E., at the base of a steep cliff of trap, stood a small chapel, now entirely removed, which was dedicated to the Virgin Mary, and there is a popular tradition that for sins of a certain carnal nature the transgressors had to do penance at "The Thougrit Stane" by going round it on their bare knees so many times each day according to the nature of the offence.

The Boulder-clay lying immediately below the vegetable soil contains, in many places, the remains of the roots of trees, mostly oaks, showing that a thick forest once covered most of this region; and the small number of places in its area bearing Celtic names shows that its population must have been sparse when Gaelic was spoken in S.W. Scotland.

The only deposit of Sand and Gravel I know of in this locality is a little to the N. of Lochlibo; it is circular in form and of small extent.

At either end of this loch small patches of Alluvium have been formed by gradual silting up from materials washed down from the higher grounds, and from the decay of water plants. The Caldwell meadows have had a similar origin, and before the Lugton deepened its channel near Bentfauld a lakelet of more than a mile in length stretched N. from that place. Its site is now fine alluvial land, and the bed of the stream running through it is overgrown with *Equisetæ*—the last remains of the aquatic vegetation. The level lands near the confluence of the Lugton and Garnock Waters, now forming part of the pleasure grounds of Eglinton Castle, are composed of materials washed down by these streams, and to this circumstance their level beauty and high fertility are largely due.

The last formation to be noted in this district is the accumulation of vegetable matter known as Peat Moss, which is found in detached patches, generally in basin-shaped hollows of varying extent. There are six such areas—Bloak, Dykehead, Auchentiber, Cockenhead, Sidehead, and White Mosses—the first named and largest containing 610 acres. A considerable area around the margins of these patches, where the moss is of little depth, has

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been brought under cultivation. Some forty years ago large quantities of peat for fuel used to be dug from all these mosses, but at present, owing to the cheapness and easy carriage of coal, the "casting" of peats has nearly been discontinued.

Trunks and roots of oak, willow, birch, and hazel trees are found in the mosses. The oaks seem to have mostly grown on the outskirts of the basins, and, judging from the remains of roots and trunks, must sometimes have been of a great size. But the stems of trees found are very few in proportion to the roots, and it has been thought that the former may have been largely removed by human agency.

Hazel nuts are often found imbedded among the twigs and branches on which they grew.

The Minutes of the Society of Antiquaries, for 17th Nov., 1791, refer to an interesting discovery made in Cockenhead Moss—"Dr. Ferris presented to the Society a shield dug out of a large moss about 1779, 6 or 7 feet below the surface, when the people who found it were casting peats on a farm called Lugtonridge, near Giffen Castle, in the parish of Beith. There were four or five more dug out at the same time, and they were observed to have been regularly placed in a ring. The possessor of the estate, Bailie John Storie of Paisley, could only procure this one, as the labourers had destroyed the rest before he had received any information of the discovery of them. It is of brass, 26¼ inches in diameter, embossed in the middle, and hollow on the other side to admit the grasp of the hand." Similar bronze bucklers have, I understand, been found at Yetholm on the Border. Probably a shallow lake once occupied the centre of this area, with a broad strip round it clad with a thick growth of birch, hazel, and willow, and that bordered by a dense forest of goodly oaks. Possibly under this forest shade those bronze bucklers were laid down around the grave of one of the tribal chiefs. Club mosses and water mosses grew, and died, their decay forming soil for their successors, the deposit spreading in extent and increasing in thickness until the lake was overspread, the brushwood overhid, the shields overgrown, and the fallen oaks buried out of sight, the peat moss we now see covering all in its dark embrace.

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No. VIII.—Phenomena of the Glacial Epoch: II. The "Great Submergence." By Dugald Bell, *V.P.*

[Read 9th May, 1889.]

Introduction.—The *Reports* of the Boulder Committee of the Royal Society of Edinburgh, which were recently completed, furnished some matters for consideration in a previous paper* with regard to the position of these travelled blocks, and the theory assigned in the *Reports* for their transport, viz., by means of floating ice or bergs. We endeavoured to show that the facts recorded as to the positions of the boulders and their lines of dispersal point rather to the agency of a great sheet of land ice. We wish now to consider an essential part of the iceberg theory when applied to account for these boulders, viz., a great submergence of the land. In one of the *Reports* referred to it is stated that, if the phenomena under discussion be due to icebergs, a submergence of some 3000 feet is thereby implied; but in this, it is added, there is nothing improbable. Few, however, will adopt this extreme view. Those who think a considerable submergence is required to account for the phenomena usually contend for one of not more than 1500 to 2000 feet.

The succession of events during the glacial epoch is generally set down thus:—

1. A period of *extreme glacial conditions*, when the country was deeply buried under land ice, like Greenland at the present day.

2. A period of gradual *submergence* to the depth in some parts of 1500, in others of 2000 feet, with glaciers still existing in the groups of islands which then formed all of the country that was visible.

3. A period of gradual *re-emergence*, during which the marine drifts formed during the second period were ploughed out of the valleys by a *second* set of glaciers, in some localities of considerable size, but smaller than those of the first period.†

Some geologists are disposed to advocate several other minor "oscillations of level" during the glacial epoch. But there seems to be a general agreement, among many of them at least, with regard to the principal submergence, *i.e.*, of the second of these

* See *Transactions*, vol. viii., part 2, p. 237.

† See *e.g.*, Ramsay's "Physical Geology and Geography of Great Britain," chap. x.; and Lyell's "Antiquity of Man," chap. xiii.

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periods, which is held to have divided the glaciation of the country into two distinct stages, and which is usually styled, as an understood and established point, "the great submergence."

Our Object.—The position we venture to take up in the present paper is, that this "great submergence" is very far from being proved. In several respects evidence is either wholly awanting or quite inconclusive; in none is it such as to put the matter beyond reasonable doubt. There is, indeed, good proof of *some* submergence during part of the glacial epoch, say of a *few hundred* feet —from three or four to five or six hundred perhaps (its limits have not yet been well defined over the country generally)—but anything more than this, or at all approaching 2000 feet, not to mention higher figures, has *not* been established, and we think, can be shown, on a review of the facts, to be extremely doubtful or open to question.

It may be a good exercise for us, then, as students of the science, to examine, with all respect for the writers who adduce them, but as thoroughly as we can, and as all true teachers in geology would wish us to do, the facts usually brought forward in support of this "great submergence."

Imperfection of the Evidence.—The first point that strikes us is the *defective* nature of the evidence on which this alleged "great submergence" rests. There are, to begin with, no distinct or traceable old coast-lines at all approaching to such a height; whether cliffs with their sea-worn caves, or shelving shores with their zones of beach pebbles, or receding bays of beds of gravel, sand, and silt, mixed with marine fossils. Nothing of the sort. The entire absence all over the country of such indications of the former presence of the sea at such high levels—assuming that it ever stood there—is remarkable. The late Dr. Robert Chambers, it is true, in his interesting book on "Ancient Sea Margins," gave a number of instances of what he took to be old sea-beaches at various heights approaching, or even exceeding, 1000 feet. But it is now generally admitted that this esteemed writer was quite mistaken in regard to those so-called high-level beaches. They are not really sea-beaches. Some of them are simply lines of weathering, where the strata are horizontal or nearly so; others are flutings formed by the action of glaciers; others are river deposits; and others again are the margins of ancient lakes.*

* See Geikie's "Great Ice Age," p. 297.

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We may say, then, that so far as beaches, or coast-lines, or undoubted marine drifts are concerned, there are absolutely no indications of anything like the great submergence contended for. And, as we shall see later on, the entire absence of these, on the supposition that such submergence really took place, is not satisfactorily accounted for by any theory that has yet been broached for the purpose.

Further. Points have been brought forward as evidences of submergence which are not really so. Sir Charles Lyell, for example, generally so clear and careful in his statements, speaks of its being inferred "from the joint evidence of marine shells, erratics, glacial striæ, and stratified drift at great heights, that Scotland was, during part of the glacial period, 2000 feet below its present level, and other parts of the British Isles 1300 feet."* It seems wonderful that Sir Charles could enumerate such particulars together and class them as "joint evidence," some of them being clearly very imperfect evidence, and others none at all, of the former presence of the sea.

Erratics and Striæ.—Erratics and glacial striæ, for example, are at least as probably the effects of land ice, nay, far more probably—for no floating ice could produce the regular continuous striæ found everywhere diverging from the main mountain chains, or cause the mingling of nearer and more distant kinds of rocks among the erratics, or leave these travelled blocks in the positions in which many of them are now found.† The confusion in Sir Charles's statement may be illustrated by saying that the kind of evidence for placing Scotland 2000 feet beneath its present level would, if held valid, depress other parts of the British Isles quite as much; and on the other hand, the kind of evidence that would restrict the submergence in those other parts to 1300 feet, would restrict it in Scotland to a little over 500 feet! Besides, if we are to conclude the former presence of the sea from such marks as "erratics and glacial striæ," we have them in Norway and North America from 3000 up to 5000 or even 6000 feet; and the question arises, where and upon what principle are we to draw the line up to which they are to be taken as proving marine action, but not beyond?

Shell-less Drift.—"Erratics and glacial striæ" must therefore be dismissed entirely as evidences of the former presence of the

* "Antiquity of Man," p. 274.

† See Author's previous paper, *Transactions*, vol. viii., p. 247.

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sea. Nor can we infer marine action more confidently from "stratified (unfossiliferous) drift," for this may have been produced by glacial action, or rivers, or lakes. Some of these deposits of roughly stratified unfossiliferous sands and gravels at high levels, which were at one time assigned to marine agency, have since been shown to be either moraine matter partially re-arranged by streams, or to have been deposited in local accumulations of water caused by the blocking up of the usual drainage during part of the glacial period.* In short, we may say of all these high-level gravels without shells, there is no certainty about them; they are utterly worthless as evidence without shells. "Professor Ramsay," we are told, "estimated the probable amount of submergence during some part of the glacial period at about 2300 feet; for he was unable to distinguish the superficial sands and gravel which reached that high elevation from the drift which, at Moel Tryfaen and at lower points, contains shells of living species."† We yield to none in admiration of Professor (now Sir Andrew) Ramsay, whose influence among geologists all over the world is deservedly high; but his own writings teach us how perilous it is to conclude the marine origin of sands and gravels from general appearance, or from resemblance to other deposits. At the time when he wrote his most interesting little work on "The Old Glaciers of Switzerland and Wales," the Professor was a thorough adherent of the iceberg theory; he believed that "Switzerland also lay beneath the sea *at least* 2000 feet beneath its present level;" that the huge blocks of Monthey, in the Rhone valley, had been transported by floating ice; and that "icebergs derived from Alpine glaciers" floated blocks equally huge to the Jura mountains. In support of this conclusion, he stated that the erratic blocks on the Jura "rest *on and in* stratified sands and gravels;" and with regard to those at Monthey, he wrote:—"Where the blocks do not rest directly on the shale that forms the hill, *they lie on and in* a sandy gravel roughly stratified, the material of which consists of fragments of granite, gneiss, limestone, and sandstone, generally well water-worn, a large proportion of the pebbles being quite rounded by abrasion like pebbles on the shore." This débris he goes on to describe as "being less angular than much of the drift of the midland counties,

* T. F. Jamieson, *Quar. Journ. Geol. Soc.*, vol. xvi.

† Lyell's "Student's Manual," 1871, p. 158.

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Anglesey, or some of the Carnarvonshire beds with marine shells. "Like these too," he adds, "it bore to my eye the signs of aqueous deposition."* Now we suppose there is not a geologist in Europe who holds that Switzerland was submerged during any part of the glacial epoch, or has the least doubt that the transportation of erratics in that country was due solely to glaciers and not to floating ice. A good many years before Sir Andrew published these sentences this had been clearly established by the Swiss geologists, from the distribution of the erratics, their arrangement in distinct areas according to the valleys, and even the *side* of the valleys to which they belonged, and other particulars. In 1863, Sir Charles Lyell, after visiting Switzerland and going over the evidence, formally withdrew his previously expressed view as to the action of floating ice in that country, and agreed with the conclusions of the Swiss geologists.† Nay, some years later, these conclusions were adopted by Sir Andrew himself as regards Switzerland, though he still, in 1872, wrote of "the sea having risen at least 2000 feet on the Welsh mountains."‡ We have entered into these particulars, not for the purpose of proving that Sir Andrew Ramsay made a mistake, which is a small matter, but for the purpose of showing how impossible it is for even the most experienced geologist, in the absence of organic remains, to assert with confidence that certain sands and gravels are marine. As Dr. James Geikie has remarked, "When we consider the conditions under which the great glaciers disappeared, we cannot but be chary of ascribing any deposits met with in the interior of the country to the action of the sea. Beds of gravel, sand, and silt occur in such extraordinary positions in the Alps and other highly-glaciated regions, that we may well pause before deciding on the marine origin of any such unfossiliferous deposits occupying similar positions in our own country."§

We submit, then, that the whole of the high-level gravels without shells are thus swept out of the reckoning. The testimony we have adduced proves that they may have had another origin than the action of the sea.

* "Old Glaciers of Switzerland and Wales," 1860, pp. 31-33.

† "Antiquity of Man," p. 247.

‡ "Physical Geology and Geography of Great Britain," 3rd ed., pp. 144 and 154.

§ "Great Ice Age," p. 297.

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Shelly Sands.—The only remaining piece of evidence we have to fall back upon are the sands containing marine shells. Of course where these are found to all appearance *as they were left by the sea* there is good evidence, and as far as we have gone, it seems the *only* good evidence, of a former sea-level. Let us see, then, how far this evidence will carry us.

Their General Height.—Scotland.—In Scotland, the highest point at which marine shells have been discovered is, we all know, at Chapelhall, near Airdrie, 510 feet above the sea. They have been found at Gamrie in Banff, at 350 feet; in Caithness and Aberdeenshire, at 250 feet; near Bothwell, at 200 feet; in other parts of the Clyde valley and elsewhere, at various lower levels down to the 40 feet beach. In these localities—none of them, it will be seen, at any great height—shells have been found of existing species, but implying a colder climate than that of the 25 feet terrace or the present sea. Assuming that the shells at Chapelhall were in place, which some doubt, for there seems to have been only a limited patch of the shelly clay, some two feet thick at most, imbedded in Boulder-clay, and it *may* have been transported; but giving this instance its full value as a genuine instance of the shells *in situ*, the result, so far as this kind of evidence goes, is that the greatest submergence of which we have proof in Scotland is a little over 500 feet, or, making allowance for the depth in which the shells may have been deposited, say between 500 and 600 feet.

England.—Now this corresponds very nearly with the great majority of instances known to occur in the British Islands, leaving out of view, for the moment, a few at higher levels, to which we shall immediately refer. Thus, Sir Chas. Lyell states:—"As to central England, or the country north of the Thames and Bristol Channel, marine shells of the glacial period sometimes reach as high as 600 or 700 feet."* Dr. Crosskey, in a recent paper on the "Glacial Geology of the Midlands," concludes that the subsidence of the Midlands during the glacial epoch could not have been less than 500 feet. He thinks it may have been more; but of this he is evidently doubtful.

Ireland.—With regard to Ireland, Prof. Jukes, writing in 1862, in the second edition of his excellent "Manual," mentions a number of localities where "fragments of sea-shells are found in

* "Antiquity of Man," 3rd ed., p. 274.

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the limestone gravel up to heights of 500 or 600 feet," and adds, "they have not yet been discovered from any greater height."* Since then, as we shall see, some have been found at a greater height; but we are safe in saying the great majority of instances in the United Kingdom are within the limits of 500 or 600 feet.

Other Countries.—It is worthy of remark that all these instances correspond very closely with the extreme height at which similar shelly deposits are found in other countries in the northern hemisphere, in Scandinavia on the one hand, and North America on the other. "The greatest height at which shell-bearing beds have been obtained in Norway is 600 feet above the sea."† "In the New World, as in Scotland and England, marine shells have rarely been traced higher than 500 feet above the sea, and 700 seems to be the maximum to which they are known to ascend."‡ Again, "In Canada and the United States, as in Europe, the marine shells are generally confined to very moderate elevations above the sea (between 100 and 700 feet)."§ "In Canada," says Sir William Dawson, "the depression, on the evidence of shells, must have been at least 500 feet."‖

So far, then, there is a very general *consensus* of evidence in favour of a submergence of a great part of the northern hemisphere to the extent of some 500 or 600 feet. We may confidently assume that similar conditions, both as to glaciation and submergence, prevailed in neighbouring lands and over the northern hemisphere generally. This is surely more credible than that some detached and limited areas were deeply submerged and others not; that Scotland, for example, was more deeply submerged than Norway and North America on the one hand, and than Wales or Ireland on the other; or that Wales and Ireland were more deeply submerged than other neighbouring parts of the British Isles. These things may be possible, but they are certainly not probable. The more limited and local, and the more variable from one point to another, such changes of level are represented to have been (while unaccompanied by volcanic disturbance of the strata) they are the more unintelligible and incredible.

* "Manual of Geology," p. 675.
† Geikie, "Great Ice Age," p. 409.
‡ Lyell, "Antiquity of Man," p. 354.
§ Lyell, "Student's Manual," p. 159.
‖ "Acadian Geology," p. 68.

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Unless, therefore, some clear and indubitable evidence appears to the contrary, it is most probable that the submergence of the British Isles during the glacial epoch corresponded very nearly with that indicated in other parts of the northern hemisphere. And this only carries us to, at the utmost, 600 or 700 feet.

Higher Instances.—We now come to those instances which have been held to establish a much greater submergence than this. There are a few localities in Wales and neighbouring parts of England and in Ireland in which marine shells have been found at higher elevations than we have yet mentioned—as high as from 1200 to 1400 feet. These we must now consider in some detail, as they are the instances chiefly or solely relied on in proof of the "great submergence."

There is a hill in North Wales overlooking the Menai Straits, whose name, Moel Tryfaen,* is well known all over the world in connection with this subject. Near the summit of this hill, in a bed of "drift" 1360 feet above the sea, marine shells of existing species have been found, indicating colder conditions than at present, though not the extreme arctic conditions indicated by other shell-beds in Britain. "Drift" of similar appearance, though without shells, is found in the neighbourhood to a height of 2300 feet, which Professor Ramsay, as we have seen, considered might indicate the extreme limit of submergence.†

Similar shelly gravels are found in the neighbourhood of Macclesfield, Cheshire, at a height of 1200 feet above the sea; and in Ireland also, in some places on the flanks of the Dublin and Wicklow mountains, at about 1300 feet.

Such, we may say, is the entire evidence on which the "great submergence" rests. Shelly gravels in a few places at about 1300 feet; gravels *without shells* up to 2300 feet; conclusion, a submergence of over 2000 feet! And this conclusion specially extended to Scotland, where, as we have seen, no shells are found over 510 feet!

The gravels without shells we have already set aside.

What these Instances prove.—If now the conclusion be stated

* Meaning "a round-topped hill of three summits."

† "Fortunately," says Sir C. Lyell, "the evidence of the sojourn of the Welsh mountains beneath the waters of the sea is not deficient, as in Scotland, in that complete demonstration which the presence of marine shells afford."—"Antiquity of Man," p. 269. Why "fortunately?" Does not this reveal a bias quite unusual with Sir Charles?

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strictly according to the evidence producible, we may take it from Dr. Archibald Geikie:—"From the evidence of marine shells, Southern Scandinavia is believed to have sunk about 600 feet below the present level, and North Wales at least 1350 feet."* To which we may add, Scotland between 500 and 600 feet, and North America about the same.

So far then as any semblance of proof has gone, the alleged submergence of 2000 feet or more becomes reduced to one of, at the utmost, 1300 or 1400 feet.

But even this, in face of the facts we have stated, is difficult to accept. It is hard to believe that North Wales and part of Ireland were more deeply submerged than the other parts of the northern hemisphere to which we have referred. Did the submergence increase southwards? That is not maintained. On the contrary, there are good reasons for believing that it rather increased northwards.

Difficulty with regard to them.—In any case, the exceptional position of these few patches of shelly gravel seems to suggest caution in our inferences regarding them. If they were really laid down, as we find them, by the sea, should we not expect to find similar deposits at a corresponding elevation in many other localities? If the sea once stood at that height, there must have been innumerable sheltered bays and inlets, narrow fiords and broad channels, at a similar level all over the country, in which marine organic remains should be found as well as here. Can any explanation be given of their being restricted to a few spots in Wales and neighbourhood, and in the east of Ireland; also of none being found anywhere between these at 1300 or 1400 feet, and the next instance in Scotland at 510 feet?

Explanation suggested—A Later Glaciation.—This brings us to consider the manner in which the absence, over the country generally, of all such traces of the sea, is usually accounted for, viz., that they were all destroyed or cleared away by the "later glaciation." In fact this second or later glaciation seems called into operation chiefly to remove the traces of the supposed submergence. It is represented to have been a "partial" or "local" glaciation; but we think a little consideration will show that, in order to do what is required of it, it must have been nothing less than a "general glaciation" over again.

* "Text-Book of Geology," p. 297.

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Explanation not satisfactory.—When we think of it, does it not seem very *unlikely* that all traces of this deep submergence (if it took place) should everywhere, with these few exceptions, be obliterated, especially by the slighter and more local glaciation which is alleged to have succeeded? It is surely unlikely that any well-marked coast-lines, for example, at various heights far inland, should be all smoothed down and effaced by this "later glaciation." Also, that all the high shell-beds which must have existed in many places should, with these two or three exceptions, be entirely cleared out and swept away by the same agency. It seems to be expecting *too much* of the glaciers—especially those smaller local glaciers which are supposed to have done the work—that they should "plough out of the valleys" all the "marine drift," or sediments of any kind, formed during the long period (as it must have been) of submergence, and "leave not a wreck behind." For, in the first place, it appears that ordinary-sized glaciers, at least, whatever may be their other effects, have but a limited power of sweeping out and pressing before them accumulations of débris. One instance that may be given is the Glacier de Miage, described by Forbes as actually divided into two, not by any fixed obstacle in the valley itself, but solely by its own moraines accumulating in front of it, and forming a mound which parts the ice with less resistance than would have been required to push the huge heap forward. Another is furnished by the Glacier des Bossons, which, instead of pushing its terminal moraine clear before it, levels itself upwards, so to speak, and rests upon it as on "a steep embankment projecting into the valley."* The well-known "striated pavements" in the Boulder-clay of our own country also show that the ice, instead of pushing the clay all before it, pressed it here and there into a compact mass, and moved on over it.

But, secondly, supposing the "ploughing out," so far as it went, were more thorough and complete vertically than we have reason to think it could be, it is impossible to believe it could be complete laterally or horizontally. There is this great difference between marine and glacial action, which renders it quite certain that no local glacier could make a "clean sweep" of the marine deposits. The sea has a most devious, sinuous coast-line—at any level it must always have had such a coast line—winding into every recess

* "Tour of Mont Blanc," pp. 27 and 3.

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and angle, into every little side valley and sheltered nook of the country; whereas a glacier keeps as straight as possible to one main channel. It does not branch off into side openings, merely because they are openings, as the sea does; but rather holds on straight across them and disregards them. In these side valleys, thus blocked up, glacial lakes may be found, like the Marjelen See and others. It is therefore incredible that subsequent local glaciers could make a thorough clearance of the marine deposits formed during a period of submergence. The glaciers could not branch off or flow out into all the curves and bays and recesses that were occupied by the sea. Whatever their action might be so far as it extended, it is simply impossible that their *area* could coincide with that of the submergence.

In another respect the clearance could not be complete laterally, or, as we may express it, *longitudinally*. In any valley which the sea had occupied to a certain height, the old coast lines and shore deposits would extend at a *uniform level* at some height along the hillsides bounding the lower part of the valley, while towards the head of the valley these lines and deposits would approach nearer to the summit level. There, and for some distance down the valley, they might be cleared out by a glacier. But it is improbable in the last degree that they would be obliterated in the lower part of the valley. The sea makes a line of uniform level; the glacier's is a *descending* line. The latter would soon cross and run beneath the former, which would then remain intact.

When we consider all these circumstances, we may safely conclude that the total absence of such deposits in other parts of the country at similar high levels is proof that they *never were there;* in other words, is proof against the submergence (of even 1400 feet or thereby) referred to.

This conclusion is certainly confirmed by keeping in mind what we have already stated, that in other countries in the northern hemisphere the evidences of the former presence of the sea terminate at about the same level as our own, with the exception of these instances which we are now considering and showing to be doubtful. It is not asserted with regard to these countries that they may have had shell-beds up to 1300 or 1400 feet, but that subsequent glaciers, with a singular unanimity or uniformity, destroyed all traces of them down to 600 or 700 feet!

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Ordinary Denudation.—The same remark applies to another cause which is sometimes assigned for the disappearance of such high-level beds (assuming them to have existed), viz., the action of the ordinary weathering agencies, included under the term "sub-aërial denudation." "Fortunately," if we may use Sir Charles Lyell's expression, we have a test case on this point in the well-known Parallel Roads of Glen Roy. These remarkable lines or shelves on the hillsides of that region are now admitted to be the beaches of old lakes that were "ponded back" in that side glen by the ice in Glen Spean and Glen More during part of the glacial period, at 1144, 1062, and 850 feet successively, above the sea. Our view is that they indicate the gradual retreat of great ice-sheet towards the close of the period. But others hold that they belong to the "second glaciation," which succeeded the "great submergence." It is certainly clear that the sea has never touched these shelves, even the lowest of them, since they were formed. It is clear also—and this is our main point at present—that at the time of their formation the ice must have been in great force—more than 1000 feet thick in the main glen—and therefore the snowfall heavy and the climate severe. The conditions, accordingly, would be unfavourable for the preservation of the higher shelves—nay, the "denudation" which undoubtedly accompanied the passing away of the ice altogether, would be unfavourable for the preservation of any of them. Yet they *are* preserved quite distinctly to this day in one of the rainiest districts, where "sub-aërial denudation" is most active, in Britain. Can anyone doubt that if there had been within the same comparatively recent period sea-beaches and shell-beds at similar heights all over the country, these would be equally and even more perfectly preserved? The sea, it is obvious, makes a deeper and more distinct notch on the land than a lake.

Supposed traces of the Second Glaciation.—We may note here that the facts from which Professor Ramsay—on whose authority it chiefly rests—inferred a "second glaciation," which cleared out of the valleys the "marine drift" that had accumulated in them during the supposed submergence—were such as these:—the banks and terraces of drift which occur along the sides of many of the Welsh valleys, and apparently mark the level of the drift at one time *right across* these valleys. Between these terraces, there is a lower "narrow channel, through which the brook runs, *bare*

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of drift and boulders," which the Professor took to mark the course of the smaller glacier which, subsequently to the submergence, *ploughed out a long narrow hollow in the drift.** But all this is very uncertain; for these "terraces" may be simply the successive lateral moraines of the diminishing glacier, including the débris which would be washed down the hillsides and lodged against them. This is the explanation given by that acute observer, Mr. Jamieson of Ellon, with regard to such terraces in many of the Scotch valleys. He remarks on the total absence of organic remains in them; also on the fact that, when carefully measured, they are found to be *not horizontal*, as they ought to be if sea-margins, but *sloping sea-wards*; further, that they occasionally contain large heavy boulders, and are associated with elongated mounds and confused hillocks of coarse gravel of morainic character. He adds, "that such terraces and mounds can be formed without the presence of the sea is very well shown by the similar deposits that occur in the valleys of the Pyrenees, the Himalayas, and other mountain chains in the interior of continents, where we have reason to believe no sea has ever entered since the glacial period."† And he gives the following illustration, showing how these terraces

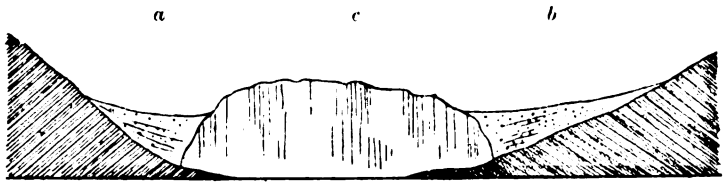

Fig. 1.—Section of Valley with Glacier in retreat. *c*, Glacier; *a* and *b*, Gravelly Débris. [From *Quar. Jour. Geol. Soc.*, 1874.]

Fig. 2.—Section of Valley after disappearance of Glacier. *a* and *b*, Gravelly Débris. [From *Quar. Jour. Geol. Soc.*, 1874.]

and the hollow between were in all likelihood formed during the gradual retreat and disappearance of the glaciers.

* "Old Glaciers of Wales," p. 10 (italics, as before, are the Professor's own).
† "On the Last Stage of the Glacial Period," *Quar. Jour. Geol. Soc.*, 1874

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We may accept this as the true explanation till some more distinct evidence be forthcoming that these high-level "terraces and drifts" are indeed marine.

The High-level Shelly Gravels.—We must now turn to consider more particularly these high-level shelly gravels of Moel Tryfaen, &c., to which we have referred. It is evident that the whole value, even of marine shells, as evidence of the former presence of the sea, depends on their being accompanied by good tokens that they are actually *in place*, or as deposited by the sea. For it is quite possible they may have been disturbed, and *lifted to a higher position* than their original bed. We have good proof that shells, like stones or anything else, can be taken from where they have been deposited, carried to considerable distances, and left ultimately in positions a good deal higher than their original place. This can be done by land ice, and so far as we know, by land ice alone. Not to detain the reader here, we give in an appendix some instances of boulders having been so carried (see p. 135). It is evident also from the striæ that the ice may be in such mass as to move straight on over and across ridges that lie in its way, and that when it does so it can carry boulders or anything else with it. If it passes over a former sea-bed, or along an old coast-line, it may take up and carry forward with it marine shells, and deposit them elsewhere, in a more or less fragmentary condition, possibly at a higher level than where it found them. The shelly Tills of Caithness, Holderness, Cromer, and Lancashire are cases in point; also that of the Endrick valley, in our own neighbourhood, described by Mr. R. L. Jack in a paper read to this Society,* as occurring from 100 up to 320 feet above the sea, and as having been most probably pushed up by a glacier from what is now the bed of Lochlomond.†

Keeping all this in mind, let us look at these Moel Tryfaen deposits and mark carefully what appearances they present. Not to rely on our own observations during a hurried visit to the

* *Transactions*, vol. v., page 2.

† "Mere fragments of marine shells in a glacial deposit do not prove submergence under the sea, for they may have been pushed up from the sea-floor by moving ice, as in the case of the shelly Till of the West of Scotland, Caithness, Holderness, and Cromer. How far this may have been the origin of the shelly Till found in high levels in Britain has still to be determined." A. Geikie, "Text Book," p. 897.

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neighbourhood some years ago, let us take them as described by a number of far more competent observers, and inquire what they indicate as to their mode of formation.

Description of the Deposits.—1. Professor Edward Forbes remarked on the usual fragmentary condition of the shells in the beds of the north-west of England, and their tolerably even distribution through the drift. He was much puzzled to account for these features, and imagined they might be due to "the ploughing up of icebergs and the great rush of ocean currents." Speaking of the Moel Tryfaen shells he said—"I have lately examined them carefully with a view to see whether they indicate an ancient coast-line or beach, or an ancient sea-bottom. But they cannot be regarded as indicating either, being a confused mixture of fragments of species from all depths, both littoral and such as invariably live at a depth of many fathoms." Such "deep and shallow water species mingled," he adds, "could at no time have lived together, or been thrown up on one shore."*

2. Sir Charles Lyell, who seems, notwithstanding this explicit declaration of the highest authority on the subject, to have always regarded these shells as being in place, and as indisputable evidence of submergence, described the deposit in which they occur as a "stratified mass of incoherent sand and gravel" near the top of the hill. "In the lowest beds of the drift," he observed, "were large heavy boulders of far-transported rocks, glacially polished and scratched on more than one side. Underneath the whole we saw the edges of vertical slates exposed to view, which here, like the rocks in other parts of Wales both at greater and less elevations, exhibit beneath the drift unequivocal marks of prolonged glaciation."† In another place he wrote of the deposit as "for the most part in thin and irregular layers, and containing here and there fragments of shells, with a few entire ones. In the lower beds," he added, "were several large boulders of far-transported rocks, glacially polished and scratched on more than one side."‡

3. Professor Ramsay admitted that "much of this drift," in the upper division of which the shells are found, "though rudely

* "Memoirs, Geological Survey," vol. i., p. 384.

† "Student's Manual," 1871, p. 157.

‡ "Antiquity of Man," p. 526.

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stratified, singularly resembles ordinary moraine matter in the appearance and quality of its mud, and the polish, approximate angularity, scratched surfaces, and sizes of its stones."*

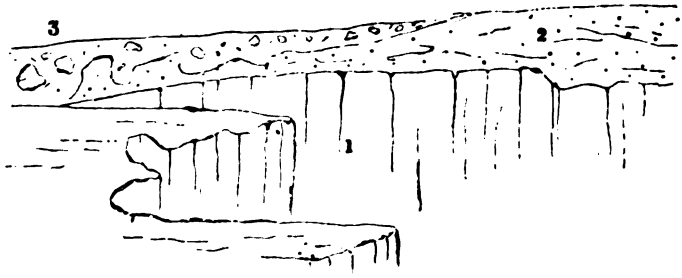

Fig. 3.—Section at Moel Tryfaen. 1, Cambrian Slate; 2, Shelly Sands and Gravels; 3, Glacier Boulder-clay. [From Ramsay, *Phys. Geol.*, p. 413.]

4. Dr. A. Geikie observes with regard to Moel Tryfaen that "the shells are broken and show such a curious commingling of species as to indicate that they are probably not really in place." And he gives other instances where fragments of shells occur in Boulder-clay, the ice-sheet apparently having "passed over some parts of the sea bottom, and ground up the shell banks that happened to lie in its way."†

5. Mr. Mellard Reade, writing on "The Drift Beds of the North-West of England," also remarks on the fragmentary condition of the shells, and the manner in which they are scattered throughout the drift. He notes that the shells most generally found whole are of a form best suited to resist pressure, and in some cases of quite minute dimensions. "Again," he adds, "the association of the various species distributed entirely without order through the clays show that they could not possibly have lived together on the same bottom, some being peculiar to sand, others to mud, some to rock, and others to shingle, some requiring deep water and others shallow; so that the conclusion is irresistibly forced upon us that they must have been to a large extent transported." The deposits vary considerably: "one part is more sandy or stony than another, one part contains gravel, and another consists almost wholly of a fine unctuous clay; but

* "Old Glaciers of N. Wales," p. 96.

† "Text Book," pp. 901-2.

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throughout are the broken and rolled shell-fragments, and the scratched erratic pebbles and boulders." Mr. Reade accounts for the phenomena, however, by the action of tidal currents and coast ice during a period of submergence and re-elevation.

It appears from Mr. Reade's description that the whole of the *low*-level drifts* of Lancashire and Cheshire, occurring from about 50 up to about 175 feet above the sea, are a series of mixed, crushed, and transported deposits, which might be characterised as a *mashed-up sea-bottom.*

6. It is almost unnecessary to adduce further testimony, but we may also cite Mr. D. Mackintosh, who considered the Moel Tryfaen deposit was due to "floating ice." He describes the "irregularly stratified gravel and sand" as containing many boulders and pebbles "which may have been *worked up from their parent rocks on the N.W. side of the hill* by waves and coast ice as the land was sinking." [It is not easy to see how this could be.] He adds:—"A large percentage of the pebbles certainly, and some of the large boulders probably, were derived from the far north." Among these he enumerates "several kinds of granite from Cumberland and Scotland," among them "many pebbles and some good-sized stones of very decided Eskdale and Criffel granite. The latter (which must have travelled no less a distance than 130 miles) is generally of the same kind as the principal variety found in the drifts of Cumberland, Lancashire, and Cheshire, and is a perfect *facsimile* of granite now quarried at Craig-Nair, near Dalbeattie. The Eskdale granite embraces several varieties with which I was familiar on the E., W., and N. sides of Eskdale, and between the latter and Westwaterfoot." Fragments of these are also found in the Lancashire and Cheshire drifts. "These granites," continues Mr. Mackintosh, "must have been carried to near the top of Moel Tryfaen by rafts of coast ice [?] when the land was too deeply submerged to permit any granite falling on the surface of glaciers terminating in icebergs. Indeed," he adds, "there is some difficulty in seeing how even coast ice could have picked up granite from the Eskdale fells at a height of nearly 1400 feet above the present sea level."† We think so too; and have a further difficulty in seeing how, having picked

* *Quar. Jour. Geol. Soc.*, 1874.
† *Geol. Mag.*, 1872.

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it up in Eskdale, coast ice could carry the granite to the shoulder of Moel Tryfaen. Would there not be coast ice there as well as here? How then, and by what skilful pilotage, could coast ice from Eskdale reach Moel Tryfaen?

Remarks.—Such being the appearances presented by the shells themselves and the gravels in which they are imbedded, we can hardly come to any other conclusion than the first part of that arrived at by Forbes many years ago, viz., that they "indicate the action of some disturbing influence—of having been accumulated far above the level of the then existing sea—through" *some* agency. Darwin suggested "icebergs;" Sir Roderick Murchison "waves of translation;" Forbes himself "the combined action of both causes;" Mr. Mackintosh, as we have seen, clung to coast ice; Mr. H. H. Howorth, a later writer on the subject, suggests a "great post-glacial flood," though it is plain that no such flood could transport pebbles and boulders a hundred miles or more, and that it must have left shells high along the sides of a hundred other channels and arms of the sea as well as here.

But indeed we may say, "'Tis past conjecture; all things rise in proof." There is every indication that these shell-beds on Moel Tryfaen are really a *glacial deposit.* The shells are fragmentary and mixed; the "drift" in which they occur is very unevenly bedded, and, Ramsay himself being witness, quite like the gravels of Switzerland. It contains, moreover, many far-travelled stones and striated boulders, mingled with pieces of rock from the immediate neighbourhood and *from lower positions on the hill itself;* and the rocks beneath are also striated. There is, in short, every evidence here of the former action of land ice, to which the formation of this "drift" is to be attributed.

This conclusion is so much in harmony with all the phenomena that we think there would be no hesitation in accepting it but for the *height* at which these shelly gravels are found. This seems to be the only difficulty; were they at the level of only a few hundred feet, this explanation would be accepted at once. Whether, after considering all the evidence there is of the former presence of ice at this point, and the evidence we have still to present of its having been in immense mass in the immediate neighbourhood, this difficulty be really formidable, the reader must judge for himself. The alternative is *submergence* to this extent, and more, with the

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various difficulties that attend it. And mere submergence does not account for the phenomena; so there has to be added to it a complicated, and in some points incomprehensible action of icebergs and coast ice and waves of translation! It is a question of probabilities:—whether the deposition of this shelly gravel was the work of land ice, whose work elsewhere it closely resembles, and of whose presence here there is ample other evidence; or of the sea, whose ordinary work it does *not* resemble, and of whose former presence at this level there is *no* other evidence.

The Irish Channel.—Additional light, we think, will be thrown upon the subject if we take a general view of what has been made out regarding the glaciation of the Irish Channel, and the tracts on both sides of it.

There is good proof that during part of the glacial epoch the Irish Channel was filled from side to side by an immense stream of ice over 2000 feet thick. Mr. Horne* found that the ice-sheet at the mouth of the Nith must have been of *at least* this thickness; and there is reason to believe it may have been considerably more—perhaps nearer 3000 feet. This ice, moving southward, was joined by the north lake ice off the Cumberland coast; and the resulting direction of the united stream became south-west. It buried and overwhelmed the Isle of Man, which is striated all over in this direction, viz., from N.E. to S.W. It was in such mass farther south that it held on its way unaffected in any perceptible degree by the ice from the Snowdon range, as Ramsay has shown. According to his observations, the great ice-flow passed straight across the openings of these North Wales valleys; and the island of Anglesey is also striated, not from the adjacent mainland, but from N.E. to S.W.†

When we turn to the other side of the Channel, viz. to Ireland, we find there, from the investigations of the Rev. Mr. Close and others, that part of an immense body of ice, originating in the mountains of Sligo and Galway in the west, moved eastwards and southwards across the country, and entered what is now the Channel near Dublin and Wicklow.‡ Here it joined the other

* "Sketch of the Geology of Isle of Man," *Trans. Edin. Geol. Soc.*, 1874.

† *Quar. Jour. Geol. Soc.*, vol. xxxii., 1876.

‡ Map of the General Glaciation of Ireland, by G. H. Kinahan and M. H. Close, Dublin, 1872.

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great ice stream from the south of Scotland and the Cumberland mountains, and must have affected to some extent the general direction of that stream. Mr. Horne believes, from the presence of chalk flints, that the Irish ice at times succeeded, "after a hard battle," in reaching the Manx coast. If so, it must have, to a certain extent, displaced or "shouldered aside" the Scotch and Cumberland ice. He says—"it is not to be supposed that the normal momentum of the respective ice-sheets remained constant. The moving force must have varied with changing conditions." And "the respective ice-sheets must have been subjected to intense compression."* It is, therefore, quite conceivable that, now on this side and now on that, the ice would be pressed up to some extent on the neighbouring land. This is what we believe did happen. The eastern side of the great united ice-stream was pressed up on the hillsides adjacent to the Menai Straits, and the western side was (simultaneously or alternately) pressed up on the hillsides near Dublin and Wicklow. It is in such situations on both sides of the Channel that these mixed and broken sea-shells are found. Can any other likely explanation be given of why they are found at these heights here, and here only?

Submarine Hollow.—This seems to be confirmed, in an interesting way, by the deep hollow which extends along the bottom of the Irish Sea, similar to the submarine hollows in the sea-lochs and along the western coast of Scotland, which Professor Geikie and others have concluded were formed by the ice, wherever its action was intensified, during the glacial period. In the centre of the Channel, between Portpatrick and the Irish coast, there is a great submarine basin, sinking from 80 fathoms to 149 fathoms, *i.e.*, having a maximum depth of 69 fathoms, or 414 feet, more than the surrounding sea-bottom. Again, between the Welsh coast on the one side and the Dublin and Wicklow coast on the other, there is also a well-marked submarine hollow, sinking from 55 to 84 fathoms, thus having a depth of 29 fathoms or 174 feet. This hollow, which, between the Isle of Man and southward to the line of Dublin Bay, dies out a good deal both as to breadth and depth, becomes again broader and deeper just where the ice would be constricted between the Irish and Welsh coasts, and where, as we have seen, it would be receiving considerable accessions on both

* "Sketch of Geology of Isle of Man," p. 23.

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sides. It looks as if the preponderating mass of ice, or its centre of weight and motion, had been shifted a little from time to time, now to this side and now to that, the result being to erode a broader channel here than elsewhere. Not only so, but there is a separate little basin near the Anglesey side, as if for a time an increased weight of ice had been compressed to that side.*

Altogether, we should say that if anywhere ice, moving over what was formerly a sea-bottom, can carry up shells with it on to the adjacent land—of which there can hardly be any doubt, and a number of instances have been already referred to—this, in the conditions indicated, seems to be a locality where such a result would most likely be produced. The characteristics of the shells and of the gravels in which they are imbedded are, as we have seen, quite in harmony with this account of them. So, too, is their position. Not in land-locked or sheltered situations, but in the immediate neighbourhood of the open coast-line, and on hill-sides which, in the circumstances described, would act in some degree as barriers to the progress of the ice. As a rule, marine shells deposited in the usual way are found in well-sheltered basins, bays, and arms of the sea; not on exposed headlands and hillsides, as we are asked to believe they were laid down by the sea in Ireland and Wales. Of course there can be no attempt to show that the position of the shells here would be so sheltered from "ploughing out" or "denudation" as to account in some degree for their being preserved.

Ireland.—We have been referring chiefly to the instance in Wales as that most frequently founded upon; but the instances in Ireland are also worth looking at for a little by themselves.

Ireland consists of a great central plain of Carboniferous lime-stone, bounded in various directions, but not entirely surrounded, by groups of mountains of older formations, chiefly Silurian schists and granite. A line drawn across the centre of the island, from Dublin or Dundalk Bay on the east to Galway on the west, will nowhere touch a higher elevation than about 250 feet above the sea.† A very moderate depression would, therefore, submerge the greater part of Ireland.

* "Great Ice Age," J. Geikie, p. 519, *et seq.* "Sketch of Geology of Isle of Man," J. Horne. (See annexed Sketch Map.)

† E. Hull, "Physical Geology and Geography of Ireland," p. 121.

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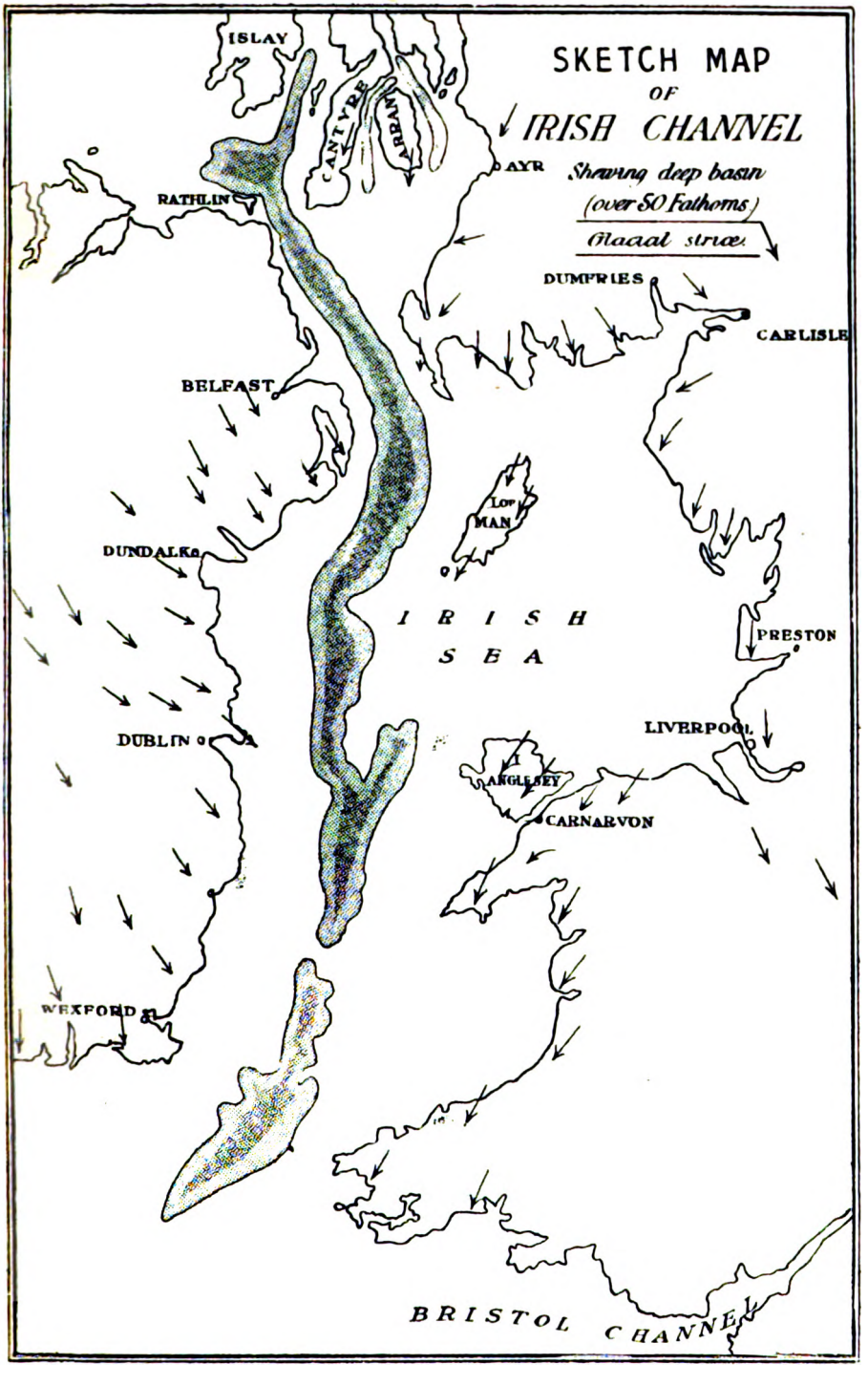

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To the north of Galway Bay, and close to the western coast, rise the Connaught and Sligo mountains, from which the glaciation of the central part of the island has proceeded.

This central plain is largely covered with what are called the "middle sands and gravels," or more shortly, the "limestone gravel," from being largely made up of pebbles of Carboniferous limestone. Now, recollecting that Ireland was glaciated chiefly by ice proceeding from the mountains in the west, and that near Dublin and Wicklow this ice, approaching the great mass that already occupied what is now the Channel, would have to struggle for a place, so to speak, with that mass—what do we find? The middle gravels rise to considerable elevations [1200 to 1300 feet] at some spots on the flanks of the Dublin and Wicklow mountains, where they are found to contain shells most of which live in adjoining seas. Mr. Close, whose labours in investigating the glacial phenomena of Ireland are well known, supposes the gravels to have been carried thither by *floating ice*, as they contain *pebbles of limestone* and other travelled stones. These limestone pebbles, Professor Hull explains, "must have come *from lower ground*," and he adds that "without some such agent as that suggested by Mr. Close, it is difficult to account for their presence."* This is the same explanation as was given of the transported and uplifted pebbles on Moel Tryfaen; coast ice and icebergs called in to do work which, for our own part, we are unable to see they could perform. Till we meet with some one who can show how floating ice can carry anything from a lower to a higher level (apart from such absurd suppositions as that of its cruising about with its burden for some thousands of years while the land was sinking) we shall hold this Irish shelly gravel found at these heights and composed largely of materials brought from a lower level to be another clear example of the effects of the great sheet of land ice—whose existence is otherwise amply proved—moving over parts of the country that had formerly been a sea-bottom, and rising, where obstacles compelled it, to some height on the adjoining hills; and shall view it as a strong confirmation of what we have concluded to be its effects also on the other side of the Channel.†

* *Ib.* p. 87.

† Mr. H. H. Howorth, in arguing for the deposition of these beds by a "great glacial flood," or "waves of translation," points out that here, in

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Thickness of the Ice.—But, we may be asked, is it possible that the ice was in such mass here as to lay down these transported shelly gravels? We think so. There is no doubt it was in mass enough to bury under it the islands of Man and Anglesey, and to pass straight across the mouths of the Welsh valleys, making the local glaciers conform to its flow; also to striate the subjacent rocks on Moel Tryfaen, and bring with it pebbles and larger stones from a far distance and from a lower level. These things have been proved, and we know of nothing else than land ice that could produce such effects. A few particulars, however, may be given on this point.

The minimum slope of moving ice is taken by Dana as 10 feet to the mile. Professor Favre of Geneva estimated the slope of the old Aar glacier towards its termination as not more than 2 in 1000, *i.e.*, about 10¼ feet per mile. From a recent article in *Nature* (April, 1889) it appears that the slope of the great Alaska glacier in its lower part is about 13 feet in a mile. Remembering that the stream of ice from the south of Scotland, joined by the Cumberland and Welsh ice on the one side, and by the Irish ice on the other, would have its surface slope well maintained, I think we are justified in taking the average slope of this great body of ice that filled the Channel at about the minimum of 10 feet in a mile. If, therefore, it was some 3000 feet thick, as there is good proof it was, among the mountains of Galloway, then here, say 120 miles south, it would still have a thickness of 1800 feet. The same remarks apply to the ice on the Irish side, which is shown to have been of at least equal thickness,* and the distance traversed by it being about the same.

Slope of Moel Tryfaen.—We may add here that though we have abundant proof that ice, when urged on in great mass, can move up comparatively steep slopes, yet, in all likelihood, the steeper the slope the less chance there is of the ice carrying anything with it. But as regards Moel Tryfaen at least, the fact is that the slope is exceedingly gentle, as will be apparent from the

the narrow part of the channel, the wave would be constricted, and so rise higher on either side. (*Geol. Mag.*, 1883). If so, such must have been the case also in every narrow channel and arm of the sea all round our coasts. But the suggestion is interesting as confirming what we have said regarding the ice sheet at this particular point.

* Close, *Geol. Mag.*, 1867.

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following sketch, copied from Mr. Mackintosh's paper in *Geol. Mag.* of January, 1872; so that, when the American geologists speak of stones having been carried up "a slope of 7° two miles long, or 16° one mile long to a height of 1400 feet" (see Appendix)—this is quite analogous to what seems to have occurred with the glacial shelly gravels in the neighbourhood of the Menai Straits.*

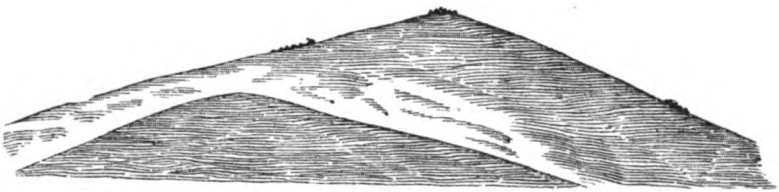

Fig. 4.—Distant view of Moel Tryfaen from near Bangor. Alexandra Quarry to left of summit. [From *Geol. Mag.*, 1872.]

We have thus endeavoured to show that these shelly gravels are very insufficient proof of such a submergence as is contended for, because (1) there is every appearance of their not being in place, and (2) their presence in the positions where they are found can be otherwise accounted for than by actual deposition by the sea at these points. We have also tried to show, from a general view of the glacial phenomena presented by the neighbourhood, how probable this other account of them is. If some readers still find it difficult to accept this explanation of them, then the only alternative is the "submergence." We have already touched on some of the difficulties attending that theory, and there are

* On the second part of his paper on the "Drift-Beds of the N.W. of England and N. Wales," Mr. Mellard Reade says—"Moel Tryfaen is a rounded mound-like plateau forming a spur of Snowdon. It is evident that the Tryfaen gravels are but an upward extension of those on the valley. There are no terraces on Tryfaen. At the Alexandra quarry, just on the summit, is a bed of current-bedded laminated sand and gravel containing large boulders. At about 12 feet from the surface I took out a glaciated stone; the rolled gravel contains travelled granite and even flints. The larger stones appear to be local" (*Quar. Jour. Geol. Soc.*, vol. xxxix., 1883). Mr. A. Taylor, F.G.S., in a paper on "Denuding Agencies," &c., points out that "glacier-eroded lakes, much lower than Moel Tryfaen, and close to it, are free from marine remains; therefore it seems difficult to suppose that a depression of 1300 feet and immersion in the sea of Tryfaen could have taken place without having left any marks on the land except at one spot." *Ib.*, vol. xxxii., 1876.

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others which we may now briefly indicate. The more clearly the difficulties in the way of accepting it are brought out, the more is the other explanation which we have suggested strengthened and confirmed.*

Sir A. C. Ramsay on the Dee.—We may gather some valuable collateral evidence from an able paper by Sir Andrew Ramsay on the "Physical History of the Dee."† In that paper, accounting for the formation of the Dee valley (in Wales and Cheshire) by the long continued action of the ordinary agencies of denudation, Sir Andrew maintains that "since the beginning of the Permian epoch, the higher ground of Wales has formed land well raised above the level of the sea," and that "North Wales was carved by slow degrees and by sub-aërial agencies into its present mountainous form chiefly between Permian times and the present day." He passes in brief review the various intervening formations to show how inconsiderable the changes of level probably were while these groups of strata were being laid down. The Permian and Trias he believes to have been deposited in inland seas or lakes when the country stood somewhat higher than now. The Jurassic formations were deposited amid groups of islands in shallow seas. The Purbeck and Wealden beds indicate "fluviatile conditions." The lower half of the Cretaceous formation was "certainly deposited near shore;" and even "during the deposition of the chalk, there is no proof that the higher parts of Wales were submerged, but rather the opposite." Later still come the Eocene deposits, "which in a large sense may be regarded as estuarine;" the Miocene rocks "are unmistakably of terrestrial and fresh-water origin; and the different members of the Crag were mere eastern shallow sea or shore deposits." Sir Andrew thus holds that, since Permian times at least to the close of the Crag, the hilly region of Wales has remained "well-raised above the level of the sea." He keeps up the head of the country, so to speak, during all "that long lapse of geological ages," and then at the end of them all, lets it

* Sir A. Ramsay, alluding to Dr. Croll's suggestion that "the Boulder-clays of Holderness, &c., were pushed forward and left on the land by the Great Northern Glacier that, coming from Norway and North Britain, filled great part of the German Ocean," says frankly, "this is the alternative if submersion is not allowed." "Physical Geology and Geography of Britain," 3rd ed., p. 157.

† *Quar. Jour. Geol. Soc.*, vol. xxxii., 1876.

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go down, down, "full many a fathom deep," at a comparatively recent time, immediately preceding our own day! But we are inclined to think that Sir Andrew, in writing this paper, must have given up the "great submergence" during the glacial epoch, for he speaks of it as a "minor submergence." Yet, according to his own former view of it, the whole country, except the higher hill-tops, had disappeared! If this was only a "minor" submergence, may we ask when was there a major?

Here we cannot fail to note how improbable it is—how inconsistent—that the smaller subsidences which have taken place since Permian times, and during which the higher grounds of Wales continued to be "well raised above the level of the sea,"—that these smaller, partial subsidences should form well-marked groups of strata which remain, and can be distinguished to the present day; and yet that a subsidence and re-emergence of the land to the extent of 1500 or 2000 feet both ways,—a total movement which it has been estimated might occupy some 200,000 years,*—could take place, and the deposition of sediment during all that time be so slight that no permanent strata were formed—nothing but some local sporadic beds of sand and gravel, which were afterwards nearly all cleared away!

To what depth, is it imagined, must the land sink, and what length of time is required before any solid strata can be formed?

The Carboniferous period, for example, we can see was one of gradual subsidence; but deposition went on, *pari passu*, so to speak, with the downward movement. The result is seen in those successive beds of sandstone, shale, coal, ironstone, limestone, which make up our Carboniferous formation. Yet it is thought that during the "great submergence," if such there was, of the glacial epoch—when the waters must have been full of sediment from the action of the ice—no deposits were formed but what subsequent *local* glaciers almost entirely cleared away! How was this? Did the land sink and rise again more rapidly at this late geological period than in earlier times? This has actually been suggested by some writers, but it has not the slightest degree of probability in its favour. The reverse is far more likely to be true, viz., that the movement was much slower than in earlier periods.

* "Antiquity of Man," p. 485.

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The South of England.—But we have yet another point in confirmation of our position to refer to. It is a noteworthy fact that, as Sir Andrew Ramsay has pointed out, "south of the estuaries of the Severn and the Thames, England is for the most part destitute of boulder drift," only some erratics being found close on the sea, which may have been brought by floating ice.* Lyell also states that "this portion of the south of England cannot be shown to have been under water at the time of floating ice by the evidence of erratics or marine shells of northern species."† And again, "The district south of the Thames and Bristol Channel seems to have remained land during the whole of the glacial period at a time when the northern area was under water."‡ And in his map showing the extent of the supposed submergence during part of the glacial period, all south of a line drawn between the estuaries of the Thames and the Severn is marked by dark lines to represent "the land which alone remained above water."§ If all this be correct, then we have this surprising result—that while "the land north of the Thames and Bristol Channel and that of Ireland was gradually reduced to such an archipelago as is pictured in map"†—that is to say, was submerged till only the summits of the highest hills appeared as scattered islets above the sea,—all south of the Thames and Bristol Channel remained clear and dry above water! In North Wales there was a submergence, at first believed to be 2300 feet, and still maintained to be about 1400 feet, while at a short distance, to the south of the Bristol Channel, this great depression died out or disappeared, so that there was no submergence at all! Is this credible? And it is a curious circumstance that the evidences of glaciation and of a certain degree of submergence go together and cease together; so that while it is sometimes said there is no trace of submergence south of the Thames valley during the glacial period, at other times it is stated there is no trace of glaciation there. Thus, Sir Andrew Ramsay says—"South of Wales, in England, I know of no definite signs of the direct action of glaciers;"‖ and Dr. James Geikie—

* "Physical Geology and Geography of Great Britain," 3rd ed., p. 157.
† "Antiquity of Man," p. 276.
‡ *Ib.*, p. 275.
§ *Ib.*, p. 276.
‖ *Op cit.*, p. 384.

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"There is no direct proof that the ground south of the Thames was ever covered with land ice."* It thus appears that where the marks of the ice cease the indications of submergence cease also; which certainly looks as if things taken to indicate submergence were really effects produced by the land ice. We can understand that an ice-sheet may terminate abruptly, and the evidences of its action cease entirely within a short distance of where it must have been in force; instances are common of ice-sheets terminating in cliffs hundreds of feet in height; but can we suppose such an abrupt termination to an actual submergence of the land?—that it could be so great immediately to the north of the Bristol Channel and nothing at all immediately to the south of it—and this without any apparent break or dislocation in the strata along that line?

Those who insist upon the truly marine origin of these shelly gravels on Moel Tryfaen, and hold that they indicate a submergence of the land to that extent, have therefore to explain how it is that there is no trace of such submergence over the south of England, where, be it remembered, there was no "subsequent glaciation" to efface it.

"*Local Depressions.*"—But it is sometimes said there may have been a "local depression" in Wales—a considerable local depression—while there was little to the north of it, and almost none at all to the south of it. This seems to be the last resort of a bewildered geologist. He must surely be at his wits' end when he has recourse to such "local depressions." There is nothing to support this theory—no such disturbance of the recent strata as to show it is even probable. On the contrary, Lyell tells us that "on the borders of Wales and Shropshire, we find the slaty beds of the ancient Silurian system curved and vertical, while the beds of the overlying Carboniferous shale and sandstone are horizontal. All are agreed," he continues, "that in such a case the older set of strata had suffered great dislocation before the deposition of the newer or Carboniferous beds, and that these last have never since been violently fractured, nor have ever been bent into folds, whether by sudden or continuous lateral pressure."† It thus appears there is no evidence in the strata of any such local disturbance since Carboniferous times.

* "Great Ice Age," p. 364.

† "Principles of Geology," vol. i., p. 315.

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It would be surprising enough that the whole country should be depressed and re-elevated 1500 or 2000 feet without any apparent disturbance of the strata; but it is impossible to conceive only some parts of it affected in that manner and to that degree without any such results being produced.

Summary.—Such are our reasons for doubting or disbelieving in this alleged "great submergence" during the glacial epoch. We have shown the imperfection of the evidence on which it rests, and its absence over the country generally; that the explanation given of that absence is not satisfactory; that in other countries of the northern hemisphere there is no proof of such a deep submergence as that contended for, or of one exceeding 500 or 600 feet; that in the few exceptional cases where marine organic remains have been found at considerably higher levels than this they bear every mark of not being in place, and are associated with tokens of powerful ice-action, indicating the cause to which their position is most likely due; that this is confirmed by the absence of all traces of such a submergence, during the same period, within a short distance of them; and that no evidence from the strata can be adduced in favour of a "local submergence," which, besides, is in itself in the highest degree improbable.

Some Submergence admitted.—We have shown that there is a very general consensus of evidence in favour of a submergence of 500 feet or thereby. But this is very different from one of 1400 or 1500 feet, not to speak of 2000 feet or more. It seems most likely that this comparatively limited submergence over a great part of the northern hemisphere during the glacial epoch was mainly due, not to an actual subsidence of the land, but to the increase and deepening in these latitudes of the waters of the sea, caused by the attraction of the great mass of ice that was then accumulated in northern regions. Dr. Croll, Sir W. Thomson, and others have shown very clearly that an accumulation of polar ice in either hemisphere would be attended with a certain displacement of the earth's centre of gravity, the result of which would be to raise the general level of the sea towards the pole where the ice was in force. These eminent physicists have made calculations as to the effect which might thus be produced upon the waters of the ocean; and though the results differ somewhat according to the different data which they respectively adopt in regard to the

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mass of the ice, or its preponderance at one or other of the poles, yet they generally concur in admitting that a rise in these waters (*i.e.*, a submergence of the land), to the extent of 400 or 500 feet in our latitude, can thus be accounted for.

Here, then, we have a *vera causa*—a real intelligible cause—satisfactorily accounting for the effect, and accounting for it *at that particular time.* For it is not only the submergence, but the *coincidence of the submergence with the glacial period*, that has to be accounted for.* In every part of the world where glaciation has been observed, at least in the neighbourhood of the sea, it is accompanied by evidence of some submergence, indicating apparently a connection between the two. And as manifestly submergence could not produce the ice—to which, indeed, so far as it prevailed, it was distinctly unfavourable—it is probable that the ice was, in this way, the cause of the submergence. This is surely far more likely than that certain movements of the internal heat of the earth, contracting and expanding the rocky masses, (which was Sir C. Lyell's idea†) should cause depressions and elevations of the earth's crust in so many countries, by a curious coincidence, just simultaneously with the occurrence of a glacial period on the surface!

But if this be the cause, of course the effect must be proportional to it. Lyell discarded it because it could not account for a submergence of 1500 or 2000 feet which he considered had to be accounted for.‡ But if it could produce one of 500 feet or thereby, we have shown some reason to hold this would be sufficient. Be it remembered, too, that a submergence of this amount would cover all the lower or alluvial parts of the country, as shown in Lyell's map—*all those parts in which evidences of submergence are certainly to be found.*

* Sir C. Lyell, after describing the shell-beds at Uddevalla, in Sweden, visited by Dr. George Jeffreys in 1862, remarks:—"It appears, therefore, that the series of movements in the district under consideration consisted, first, of a depression converting the shallow water into deep sea at a time when the cold was very severe; and then of an elevation of more than 200 feet when the waters of the sea had acquired their present milder temperature" ("Principles," vol. ii., p. 193). We have thus severe cold and depression, milder temperature and elevation. This looks as if the two sets of phenomena were somehow related.

† "Principles," vol. ii., p. 135.

‡ "Principles," vol. i., pp. 289-291.

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Conclusions confirmed by N. America.—Our acceptance of this as the true or chief cause of the submergence during the glacial epoch is greatly confirmed by the light cast upon it from the North American continent. There we find the phenomena on a great scale,—the characters "writ large" and clear, so to speak—free from the complications produced on this side by the meeting of the separate ice-streams passing between islands and over old sea-channels. According to theory, if this be the true cause, the submergence should *increase towards the north.* And this is precisely one of the points observed by the American geologists, and which they have brought out most clearly. Thus Dana states it:—"The height of the sea-border formations increases in going north. On the southern shores of New England the height above the sea is 40 to 50 feet; at Point Shirley, near Boston, 75 to 100 feet; on the coast of Maine, in some places, 217 feet; on the shores of Lake Champlain, at different heights up to 393 feet, and containing marine shells to a height of 325 feet; on the borders of the St. Lawrence, with abundant marine fossils near Montreal, to a height of 460 feet. . . . On the coast of Labrador the beds are 400 to 500 feet above the sea."* And farther north, in the Arctic regions, at higher levels still.

How different is this from what he has to say regarding Britain —that "the depression varied in different parts from 1300 to 500 feet, except over southern England, where it may have been only 100 or 200 feet" (p. 555). There is no sequence or connection here. But if we leave out the 1300 feet in the middle as not proving submergence, the other terms fall into something like uniformity with the facts observed on the North American continent.

This theory dispenses entirely, or in great measure, with any actual movement of the earth's crust during the glacial period, though there may have been, to some slight extent, and from the same cause, an actual depression. The supposition, however, of great local depressions and re-elevations within such a comparatively recent period, is, as we have already shown, in many respects improbable. Some further considerations on this head may be added ere we close.

Movements of the Earth's Crust.—According to the latest investigations of physicists, vertical movements of the earth's crust are of two kinds—(1) Those connected with compression, or which

* "Manual," p. 550.

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take place in volcanic districts, and are usually accompanied by earthquake movements and fractures or displacements of the strata, which of course cannot be restored to their original position; (2) Those slow and secular movements, independent of volcanic or earthquake phenomena, and extending over large areas and during indefinitely long periods, which seem to result from certain gradual disturbances of the equilibrium of the crust by the progress of denudation and the accumulation of sediment, or by the heaping up of ice and snow in certain areas.* So far as they may be due to actual movements of the earth's crust, it is evidently to the latter class that the changes of level we have been considering belong. And it is from such slow movements of elevation and depression, observed as taking place in certain parts of the world—in Scandinavia and Greenland, for example—that the measure and comparison of the movements during the glacial period have been taken, and we think rightly taken. It is from these that Sir C. Lyell took the average vertical movement of 2½ feet in a century, from which he computed the time required for the total downward and upward movement during the glacial epoch as some 200,000 years. But we think the error lies in assuming that the movement can go on to 2000, or even 1500 feet. In those countries which furnish the facts on which the calculation is based, there is *no trace* that the movement has gone on to anything like that extent; on the contrary, it appears to be an oscillation or movement of the crust restricted to very narrow limits indeed.

The view that is undoubtedly gaining ground among geologists is that our earth is a planet *with a history*—it is a gradually cooling and consolidating body. Hence many of them believe, what seems very probable from all that is known of its structure, that these movements of the crust have been gradually diminishing in intensity during the ages of geological history. The earlier formations they regard as giving evidence of greater plasticity—of being subject to greater changes, both of depression and elevation, than the later ones. Thus, Dr. Prestwich, referring to the latest changes of level of which we have any evidence, amounting to from 50 to 70 feet, remarks:—"Such is the result of the last of those movements which we have traced through all geological history. Continuous for long periods in the earlier times, and

* See Fisher's "Physics of the Earth's Crust," and Prestwich's "Geology."

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productive of settlements to be measured in Cambrian times by thousands of feet, they have gradually diminished in intensity and power, until in the later geological times these great slow continental movements become limited to hundreds, and in more recent times have become reduced to, so to speak, tens of feet, or to a state of comparatively stable equilibrium."*

To the same effect Sir J. William Dawson, in his Presidential Address to the British Association at Birmingham in 1886, states his view that, as a consequence of gradual cooling and contraction, and the foldings of the strata caused thereby, the earth's crust is now thicker and stronger, and its great ribs of crushed and folded rock are more firm and rigid than at any former period. "And thus," he says, "there are enormous physical difficulties to any theory of the alternations of the oceanic and continental areas, except locally at their margins." There has therefore been, he concludes, a general "permanence of the position of the oceans and continents throughout geological time."

This, if we may venture to say so, appears to be a far more rational and philosophical view—more in accordance with geological facts, and with any intelligible theory of the history of our globe—than to hold with M. Hébert, a French geologist, that "the distinguishing characteristic of the Quaternary period is the great intensity and wide extent of these oscillatory movements of the crust of the earth. During all time," he adds, "the terrestrial crust has been subject to slow and incessant oscillations, but they never attained such proportions as during the period referred to."†

It may be so; possibly the earth's crust may remain comparatively quiescent for countless ages, and then begin a series of wide oscillations when touched by colder climatic conditions,—sinking till all but the highest hills are out of sight, and then, strange to say, after scores of thousands of years, regaining its former position, with very little to show for its prolonged immersion! It may be so; all we say is, it seems improbable, and the evidence for it should be clear and strong.

Apparently some writers in geology do not realise how much they demand when they ask us to believe in great depressions of the land, and great changes of level, at such a comparatively

* "Geology," vol. ii., p. 525.

† "Les Oscillations de l'Ecorce Terrestre pendant les periodes Quaternaire et Moderne."

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recent time as the glacial epoch. Some of them are ready on the slightest provocation to dip down whole continents beneath the sea, and that not once but several times, to suit the requirements of some favourite theory.*

How different all this is from the sure philosophic instinct of Darwin! In letters to Sir J. Hooker and Sir C. Lyell, given in his recently published "Life," the great naturalist says:—"I must maintain that I have never let down nor upheaved our mother earth's surface for the sake of explaining any one phenomenon. . . I must still think it a bold step . . . to sink into the depths of ocean, within the period of existing species, so large a tract of surface." Again—"It shocks my philosophy to create land without some other and independent evidence." And again, speaking of Forbes imagining a continent extending within recent times to North America, and others requiring one from New Zealand to South America, and even extending to every island in the Pacific and Atlantic Oceans, he says he gets "quite wroth about these supposed continents submerged within the period of existing species."† He grants they "would remove numerous difficulties" that perplexed him, yet he could not honestly admit them. And we know how his determination in rejecting all such "rough and ready" means of explaining the phenomena of the distribution of life, and his patient attention to other causes, were rewarded by rich and fruitful discoveries regarding the means of dispersal available for both plants and animals.

Conclusion.—Let the same wise caution—the same rule of "parsimony of causes"—guide us in seeking to interpret aright the phenomena of the glacial epoch. Discarding these supposed subsidences and re-elevations, these great oscillations, whether local or more general, of the earth's crust in comparatively recent times, and fixing our attention on the *one single cause*—the severe and protracted change of climate, of which we have such abundant proofs, and which *on any theory* must be admitted—let us try whether by means of it, if we but patiently work it out, all the phenomena in question may not receive a consistent and satisfactory explanation.

* It reminds us of De Quincey's story regarding Charles Lamb and his bathing attendants, who were in such haste to immerse him that they plunged him over head three times before he found breath to explain that he "was to be di-di-dipped only once."

† "Life," vol. ii., p. 38, 58, &c.

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APPENDIX.—Transport of Boulders from Lower to Higher Levels.

Instances.—In the American Government Report on the Geology of Pennsylvania reference is made to the Oriskany and Helderberg erratics on the sides and crest of the Kittatinny Mountains, where blocks have been carried up a slope of 7° two miles long to a height of 1300 feet; and in another place, up a slope of 16° one mile long to a height of 1400 feet. "The ice has actually borne them to a higher level" (p. xvi.). "The writer found a boulder of Helderberg limestone perched upon the summit of the Kittatinny Mountains which had been lifted more than 1000 feet above its natural outcrop. Another boulder of the same limestone, 20 feet long, lies on the south side of the mountain, having been carried over its crest and several miles beyond" (p. 22). Sometimes, the Report states, boulders have been carried from one mountain to another across an intervening valley; sometimes lifted from a valley to the top of a mountain; and sometimes "carried from one valley to another after being lifted *across* a mountain range" (p. 31). Hitchcock, Dana, and other writers mention as a common fact the occurrence, in North America generally, of erratics at considerable heights, 2000 feet and more above the rock masses whence they were derived; and some of them 150 or 200 miles distant from their parent bed.*

In Scandinavia, where the ice also attained a great thickness, it passed from the Gulf of Bothnia and Jemtland westward, *against* the slope of the land, crossing the Norwegian mountains, and so finding its way into the North Sea. "At Areokutan, Tornebohm found blocks at a height of 4500 feet which could not possibly have come from any place higher than 1800 feet." †

In our own country similar instances are known, though on a smaller scale. In Galloway, for example, Mr. Horne found large erratics of granite on Merrick up to a height of 2764 feet, the highest point reached by the granite *in place* being only 2270 feet. (Geikie, "Great Ice Age," p. 200.)

And we are familiar with rock surfaces striated upwards at various angles, up to as high as 40°, or even more, as in an instance lately disclosed at Bowling reservoir. Other instances have been observed at Lochlomond, Loch Katrine, and elsewhere.

* Dana, "Manual," p. 530, &c. † Geikie, "Great Ice Age," p. 404.

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It is quite clear, then, that the ice may be in such mass as to move straight on, over and across ridges that lie in its way, and that when it does so it can carry boulders or anything else with it.

Dr. J. Geikie, in his "Great Ice Age," gives a rather elaborate explanation of "the occurrence of erratics and perched blocks at higher levels than the rock masses of which they formed a part," treating of how stones "apparently travel upwards through the ice," &c. It is no doubt all true, but we think the following diagram from the American Report brings the matter more clearly

Fig. 6.—Transverse Section of Godfrey's Ridge, Cherry Valley and Kittatinny Mountain at the Delaware Water Gap, showing probable height of the ice. [Reduced from Pennsylvanian 2nd Geological Survey, p. 12.]

before the mind, and enables us to see how the thing took place. The great point is that the ice be in sufficient mass to travel with an easy slope over all the intervening elevations.

Since the foregoing was read to the Society my attention has been called to the fact that similar views in regard to the absence of proof for the alleged "great submergence," and in regard to the true nature of the Moel Tryfaen and other high-level "shelly drifts," have been expressed by several eminent geologists.

I. In the *Geological Magazine* for April, 1889 (published shortly after this paper was written), there is a notice of "The Work of Professor Henry Carvill Lewis on Glacial Geology," by Mr. Warren Upham of the U.S. Geological Survey. Professor Carvill Lewis died at Manchester, July, 1888, in his thirty-fifth year. Though young, he had taken a high place among geologists both in the Old World and in the New. He had given special attention to the glacial drift of North America, and his investigation of the "great terminal moraine" of Pennsylvania and neighbouring districts, published in the Reports of the U.S. Survey, may be said to have "completed the demonstration of the formation of the North American drift by the agency of land ice." On this side of the Atlantic he had made minute and extensive observations on the glacial drift of England, Wales, and Ireland, and had traced the terminal moraines formed by the British ice-sheets over a great part of the United Kingdom. He was, indeed, busily engaged on this subject at the time of his lamented death. Mr. Upham continues:—

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"Another very important announcement by Professor Lewis relates to the marine shells, mostly in fragments and often worn and striated, found in morainic deposits and associated kames 1100 to 1350 feet above the sea on Three Rock Mountain near Dublin, on Moel Tryfaen in Northern Wales, and near Macclesfield in Cheshire, which have been generally considered by British geologists as proof of marine submergence to the depth of at least 1350 feet. These shells and fragments of shells, as Lewis has shown, were transported to their present position by the currents of the confluent ice-sheet which flowed southward from Scotland and Northern Ireland, passing over the bottom of the Irish Sea, there ploughing up its marine deposits and shells, and carrying them upward as glacial drift to these elevations, so that they afford no testimony of the former subsidence of the land. The ample descriptions of the shelly drift of these and other localities of high level, and of the lowlands of Cheshire and Lancashire, recorded by English geologists, agree perfectly with the explanation given by Lewis, which indeed had been before suggested, so long ago as in 1874, by Belt and Goodchild.* This removes one of the most perplexing questions which glacialists have encountered, for nowhere else in the British Isles is there proof of any such submergence during or since the glacial period, the maximum known being 510 feet near Airdrie, in Lanarkshire, Scotland. At the same time the submergence on the southern coast of England was only from 10 to 60 feet, while no traces of Raised Beaches or of Pleistocene marine formations above the present sea-level are found in the Shetland and Orkney Islands. The work and writings of Professor Lewis emphasize the principle that glacially transported marine shells and fragments of shells, which occur in both the Till and Boulder-clay and the modified drift in various parts of Great Britain, are not to be confounded with shells imbedded where they were living or in raised beaches, for only these prove the former presence of the sea."

II. In the same magazine (the *Geological*) for 1883 there is a paper by Mr. H. H. Howorth containing several extracts from Mr. Belt's paper, to which reference is made in the passage just quoted. Mr. Howorth is there advocating the theory of "a great post-glacial flood," with which I do not meddle at present; but some of his observations on the subject of the alleged submergence are quite in accordance with those I have ventured to submit. "We must inquire," he says, "how it is that these drifts with shells are not found in the interior of Great Britain, and only in isolated patches along the shore. Surely if the land were generally submerged, as is assumed, even for a comparatively short time only, we should find shell-beds in various parts of England, and not merely in the Severn valley and on points near the coast. In regard to this absence Mr. Geikie says:—'If arctic shelly clays ever occurred in as thick beds in the inland as in the maritime districts, surely we should have found some notable trace of them. It will not do to lay the blame of their disappearance on that geological scapegoat, *denudation*. Denudation has not run

* *Nature*, vol. x. *Geol. Mag.*, Dec. 2, vol. i.—A similar opinion was held fifty years ago by Mr. James Smith, though he attributed the drift to debacles instead of glaciation. *Researches in Newer Pliocene and Post-Tertiary Geology*, pp. 11, 16.)

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off with the kames; why should it have been less considerate with the clays? . . . In Norway and Labrador and Maine the shelly clays are restricted, precisely as in Britain, to the vicinity of the sea coast.'" (*Geol. Mag.*, vol. ix.)

Mr. Howorth then goes on to quote from Mr. Belt:—

"Where was the shore of that mythical sea under which England, nearly to the Thames, is supposed to have been submerged? How is it that not a single undisturbed bed of glacial shells has been found, that nearly all are broken to pieces, that many fragments of *Cyprina* exhibit glacial scratchings, and that not a single instance has been recorded of the valves of a Lamellibranch having been found together? Was there no friendly cliff or cavern able to preserve a single shell from the ruthless second advance of the ice?"

What is true of England, adds Mr. Howorth, is true also of Ireland and other places. How comes it, he asks, that no marine shells, except near the coast, are found in the drifts of the Continent? He quotes again from Mr. Belt:—

"Excepting around the northern border of the Baltic, and just as far as, and no further than, the Scandinavian glaciers reached and carried up fragmentary shells from the arms of the sea which they had crossed, the northern drift does not contain sea-shells or any other marine organism. To believe that Europe gradually sank down below the level of the sea until the latter had its shore line more than 1000 feet up the flanks of the mountains, and that it rose again, without the sea leaving behind it any traces of life . . . is an extreme hypothesis, and contrary to all we know respecting the composition of sea-bottoms. . . . There is much evidence to show that vast continental areas were never below the sea level from the close of the Palæozoic period up to the end of the Tertiary period. Yet, after this stability of surface over such an immense period of time, no hesitation is felt, in the comparatively insignificant glacial period, in sending the surface of the land thousands of feet higher that ice may accumulate on the now low ranges, and thousands of feet lower that icebergs may float over the submerged lands; and no difficulty is expressed in believing that it should finish its wonderful oscillations by regaining the level it had before the glacial period commenced! It seems a burlesque on science that such theories should be prevalent amongst our geologists." (*Q. J. of Science*, vol. vii.)

This, expressed with admirable clearness and force, is precisely what I have attempted to urge in the course of my paper. I have only to express my satisfaction at finding that these conclusions—to which I had gradually been led from the best consideration I could bestow on the subject—have been so powerfully supported and confirmed. D. B.

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No. IX.—The Surface Geology of Paisley. By the late Matthew Blair.

[Read 10th January, 1889.]

The few remarks which I intend making to-night have reference to the Surface Geology of Paisley—a subject which, in my humble estimation, ought to commend itself to every advanced schoolboy, as well as to every grown man in the community. I shall commence with the locality where we are met,* or rather on the hill behind, which, I daresay, you will agree with me is a good centre to start from.

Oakshaw Hill, as most of you know, is composed principally of Boulder-clay, which contains about the same percentage of boulders as is found in this deposit in other parts of our district. The late Mr. Smith of Jordanhill tabulated them as follows:—

Sandstones, Shales, &c.,	60 per cent.
Traps,	30 ,,
Clay, Slate, and Greywacke,	10 ,,
Granite,	1 ,,

In Paisley and neighbourhood, however, as far as my observation has gone, they are made up in something like the following proportions:—

Sandstones and Shales, including Coals,	50 per cent.
Traps,	33 ,,
Limestones,	10 ,,
Clay, Slate, and Greywacke,	7 ,,
Granite,	10·1000 ,,

I know of only three points where granite boulders have been found—1st, in the Boulder-clay at Mill Street Quarry; 2nd, at a spot where the Canal Railway crosses the road between Paisley and Johnstone; and 3rd, at the excavations for the new dock on the River Cart, on the top of the rock below the brick- or shell-bearing clay. At the latter place there were marine shells adhering to the boulders, three in number, although, in my opinion, they were deposited in the spot where they were found by the action of the drift, or dropped by an iceberg during the later formation. They appear to have come from Ben Awe, the rock of which they most resemble in structure; and the only agency that we know which could have effected this transportation is the agency of ice.

* The substance of this paper was originally read to the Geological Section of the Paisley Philosophical Society.

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But to return to Oakshaw Hill; the upper surface is made up of mould or soil about one foot in thickness. Beneath this thin covering, Boulder-clay of a dark bluish or reddish colour is found over the entire surface. Many of the boulders are of a compact nature, being composed of limestone, basalt, and the harder varieties of trap, and exhibiting the beautifully-seen scratches or striations which they must have received during the "Glacial Epoch." Oakshaw Hill appears to be a fair type of the similarly rounded hills in the district. Woodside Hill, Saucel Hill, Hunter Hill, Dykebar Hill, Stanley Hill, Barshaw Hill, &c., are all composed of pretty much the same materials, and no doubt owe their origin to the same order of causes. The Boulder-clay of these hills belongs to two distinct members, and, in my humble opinion, owes its origin to two separate conditions in the region which now forms this tract of country.

The junction between the upper and lower series has been exposed in several cuttings which have been made within the last few years, such as the excavations for the Coats' Memorial Church in High Street. The upper clay is easily distinguished by the tenacity of its matrix, as also by the large percentage of boulders which it holds, of all sizes from small pebbles to blocks of many tons weight. The lower clay attains a much greater depth, although less uniform in its deposition. It is largely mixed with sand and gravel, and contains a much lower percentage of boulders, although those found are as large in proportion as the largest individuals in the upper clay. In some places one of the clays is wanting, the higher resting on the rock, or the higher being absent and the lower underlying the surface soil.

On the south-eastern slope of Oakshaw Hill the Boulder-clay is covered by a layer of sand mixed with a large percentage of mud; it is water-bearing, and is known as running sand. It thins out on the hill, but increases in thickness as it recedes outwards. This running sand passes up into a compact clay known as the *brick-clay*, or shell-bearing clay. It is first seen at the Messrs. Parlane's property, 97 High Street, and is continued eastwards to the river, forming the subsoil of the east portion of High Street, the Cross, and Moss Street, extending southwards to the Infirmary and beyond. It certainly runs out on the face of Saucel Hill at the railway. Proceeding westwards, the shell-bearing clay runs out, as I have said, at the Messrs. Parlane's property,

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and re-appears at the Museum; indeed, one of the front pillars has its foundation on a mussel bed. It again disappears at the Coats' Memorial Church, and the Boulder-clay comes to the surface.

In George Street, a little to the south, at a lower level, the rock rises to the surface west of Barr Street, continuing westwards, at a depth of 2 to 10 feet from the surface, until we pass Maxwellton Street, where it dips to the west and disappears. When near the surface in George Street, the underlying Carboniferous rocks disclose, amongst other minerals, a coal seam from 4 to 9 inches in thickness. Maxwellton Street, Queen Street, Cross Street, and Castle Street are almost built on the rock, which comes so near the surface that the foundations of several of the houses must actually be placed on it. As far as my recollection serves me, the rock which lies below Queen Street, &c., is an impure limestone.

Towards the north end of Castle Street, the rock is either covered by, or impinges against, a bed of brown sand, which increases in thickness towards Broomlands and Sandholes, where it becomes the subsoil. I have not ascertained its thickness, but it must be a good many feet.

The strata continue near the surface south of Castle Street until, topped by a massive sandstone, they disappear under Castlehead at the railway. They are again exposed along the Canal Railway eastwards to Camphill, beyond which they dip under the Boulder-clay and shell-bearing clay. Rising again to the surface at Causeyside, they have been cut through by Espedair Burn, forming a valley or ravine, but with this interruption they continue at the depth of a few feet from the surface past Blackhall Buildings to Blackhall House, where they dip eastwards, again rising to the surface in the form of intrusive dolerite and a burnt coal bed at Jenny's Well. During their course there are exposed several seams of shale, coal, limestone, and other strata, which, from the waterfall at the Hammils to the section exposed at Hawkhead Bridge, have a continuous dip to the east or south-east.

When we turn our attention to the north side of Oakshaw Hill, towards the low-lying district of St. James' Park, or the Racecourse, we would expect, from the flat appearance of the surface, that the subsoil would be somewhat uniform. But that is not the case: for although the brick-clay rises on the slopes of the hill at

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Underwood and attains great thickness in Caledonia and Love Streets, yet at the eastern extremity of Mossvale Street the Boulder-clay rises to the surface, while at Greenhill Road, also at Ferguslie School and north of Craigielea, the sandstone rises to the surface. At the latter place it was long quarried for building purposes. On the north side of the Hill a new member of the surface series appears as the subsoil, on the top of the brick-clay, namely, Peat Moss. As far as my observation has gone, this material is not met with in the southern district of the town. It, however, was got in the foundation of St. James' Church, and in several other places in the neighbourhood. Peat, or a substance akin to it, was also met with in the foundation of the New County Buildings at the corner of St. James and Love Streets. It occurs at a depth of 2 feet, resting on the shell-bearing clays. The Boulder-clay retains its normal relative position northwards towards the Clyde, rising to the surface at Laighpark, and dipping as far as the rock will allow it at Nethercommon, where it is covered by the entire series of muddy sand, gravel, shell-bearing clay, upper gravel, and surface soil. The sandstone strata rise towards the east at this point until they reach the surface at Netherhill, where they were recently quarried for building purposes.

The excavations for the new harbour on the River Cart near this spot have exposed a new member of the surface deposits which I have not observed at any other place, neither do I know of it being referred to by any writers on the subject. It consists of a dark brown laminated clay, about 2 feet in thickness, which is deposited on the surface of the Boulder-clay, and is as different from it as a log of wood in a condition of pulp is from a bed of coarse gravel. The laminations are so fine and the contact with the Boulder-clay (which at this place is dark in colour) so sharp, that you can touch the junction with the point of a needle.

This laminated clay follows the sinuosities of the uneven surface of the Boulder-clay, on which it rests, and although in one place the Boulder-clay has its level raised 20 feet higher than at another, this brown laminated clay follows its course, and retains its uniform thickness. It contains very few stones, if any, and, so far as my observation has gone, is as destitute of organic remains as the Boulder-clay it covers. But as I have neither washed it nor examined it with the microscope, I advance no opinion.

The sinuosities formed by the Boulder-clay, and followed by the

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brown laminated clay, are filled up with the muddy or running sand, by which it is covered, and the junction between these two is very marked. I have not seen any organic remains in this stratum. It has a thickness of from 4 to 9 feet, with an abundance of concretionary or "fairy" stones. It becomes much more impregnated with mud or clay as it rises to the surface; and although it has a rather uneven bottom, it presents a comparatively level surface for the brick-clay and shell-bearing clay to rest on. This bed of shell-bearing clay, which attains a thickness of from 7 to 12 feet, is covered by a bed of gravel and sand about 4 feet thick, topped by 14 inches of surface soil, much filled with roots. It appears to be made up of sand, clay, and vegetable loam. The Boulder-clay appears to rise and fall, following northward in a general way the surface presented by the strata until a point about a mile above Inchinnan Bridge, where it dips beneath a great deposit of sand, mud, and gravel. It is not touched at a point 500 yards above the bridge at a depth of 60 feet. This immense deposit of mud, sand, and gravel is continued northwards to a point 50 yards from the junction of the Cart with Clyde, where the Boulder-clay again comes up to within 12 feet of the surface, below a bed of sand and gravel. It again dips towards the river; for at the junction of Cart and Clyde, 50 yards further north, nothing but sand is found at a depth of 45 feet.

[At the excavations of the new harbour on the Cart the horns of *Bos primigenius* were found at a depth of 14 feet from the surface; and a few years ago the *scapular bone* of the Irish Elk, *Megaceros Hibernicus*, was found at about the same depth in a clay-field on the west side of the river; and one of the horns of this animal was found at the excavations for the last gasometer which was erected at the Paisley Gasworks. The last two specimens are in the public museum. These remains point to the existence of those animals on the higher portions of our district, when the lower parts (including all the low-lying districts around Paisley) were many feet below the sea, which covered and deposited the materials which make up Greenlaw.]

There can be little doubt that the Boulder-clay underlies this depression, for it is found resting on the strata right under the west end of Inchinnan Bridge, at a depth of 93 feet. The strata dip towards Renfrew for a few hundred yards north-east, close to

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the spot where the Earl of Argyll was taken prisoner in the year 1685. The depth of the alluvial soil is 95 feet.*

You will thus note that, from a point about a mile-and-a-half from the junction of Cart and Clyde, the Boulder-clay has a dip of not less than 80 feet from south to north, when it again appears at a single point 12 feet from the surface, and afterwards disappears beneath the sands of the Clyde. This points to a different condition from that in the neighbourhood of Paisley, and leads to the conclusion that long after the last elevation of the land, which raised all the low-lying parts of the town above high-water mark, that portion of the River Cart to which I have alluded formed either part of a deep lake or an arm of the Firth of Clyde which extended well up to Paisley, and which certainly did extend eastwards above the spot where Glasgow Bridge now stands, and before it got filled up by the detritus from the higher parts of the valley.

But what of the brick-clay with its arctic shells, which forms such a large part of the subsoil of nearly all the low-lying streets in Paisley? It would appear to have been deposited long before the last elevation of the land, when the lower parts of the town were not less than 60 to 80 feet below a sea in which were deposited stones and mud by means of floating land ice or icebergs, the chief part of the materials being derived from the washing down of the Boulder-clay from the higher lands, some districts of which have been almost denuded of all the Boulder-clay that they ever possessed.

But it would appear that many ages before the period of which we speak, from the evidence to be found on our highest mountains, the entire area of Scotland was probably submerged to a depth of

* I may relate an incident connected with this spot which occurred in 1832. In the summer of that year a number of unemployed weavers were engaged removing sand from the bed of the river at the lower portion of Colin's Isle. At about 3 feet from the surface one of the weavers dug up a silver shoe-buckle about the size of the palm of one's hand. It had a crest on it. The find was taken to Paisley and offered for sale to a silversmith, who refused it. It was afterwards offered to another, who weighed it, and gave the weavers 7s. 6d. for it. He broke it with a hammer before their eyes, put the pieces into a pot, and the weavers adjourned to a public-house and drank the money. Had this ornament any connection with the Earl of Argyll, who, being pursued during the Monmouth rising, crossed the river about this spot on foot, was taken prisoner at the spot indicated, and was afterwards executed at Edinburgh?

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not less than 2000 feet, during which period the upper division of the Boulder-clay was deposited.

Before this great depression took place, or during its earlier period, and during much more intense conditions of cold than afterwards prevailed, the great ice-sheet covered the land to a depth as great or greater than that of the waters by which it was succeeded. The ice may have been so thick as to have displaced the water outwards in all directions from what is now our borders, denuding every material over which it pushed. It is to this ice-movement that we ascribe the striated surface of the older rocks when their surface deposits were first removed; and, in my humble opinion, it was during this period that the nucleus at least was formed of those mounds of sand and till which form the interior of the green rounded hills which go so far to diversify our district and impart to our landscape its principal item of beauty.

Before proceeding to look at the eastern district of Paisley, I would point out the ridge of rocks at the Hammils. The platform which forms the south bank of the Laigh Linn consists of a fine-grained sandstone, the thickness of which I cannot give. This sandstone is topped at the Craigs, which form the north margin of the High Linn, by a seam of soft shale about 1 foot thick, which is covered by about 1 foot 6 inches of a harder material. It appears to contain a large quantity of iron, being what I would call a ferruginous shale, and the series is covered by a bed of coarse-grained sandstone, about 6 feet in thickness, which forms the bed of the upper portion of the river at this point. The continuous removal of the soft shale by the overflow of water has caused the ridge to retreat southwards through the undermining of the upper strata, and there can be no reasonable doubt that at one time the entire series extended northwards in line with the fine-grained sandstone, which then had an elevation of not less than 20 to 26 feet above the level of the lower part of the river. The dip, as I have already said, is towards the south, and the retreat of this escarpment is as sure an indication of the age of the river as days measure out the length of a year, or years the length of a century. Geologically considered, the age of the lower part of our river is of recent date. Compared with such rivers as the Elbe and the Rhine, it is an infant of days.

In crossing the river, we shall first look at the foundations of

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the Town Hall. The southern half of its west front is on the Boulder-clay at a depth of 37 feet from the surface. When the excavations had been made 22 feet below the bed of the river the clay was as dry as the floor of a room. The northern half, which contains the clock tower, is founded on a crystalline dolerite at a depth of 28 feet from the surface. This rock forms an intrusive bed which lies parallel with the other strata, and is covered by a seam of shale of from 1 to 2 inches thick, with a coal-bed above it, which was so pure that it was used, so far as obtainable, for fuel to fire the engine of one of the cranes which was working at the excavations. The coal is covered by a bed of calcareous shale, which increases in thickness northwards as it disappears under the street at "Old Smithhills." The usual series of mud, sand, clay, and gravel bring the alluvial soil to the surface, near which were found a considerable quantity of hazel-nuts.

Crossing over to the Abbey Church, we find that the west gable has taken a swing from the perpendicular. This was accounted for by Mr. Salmon, the architect who had charge of the restorations, by the presence of a bed of peat which passes under the foundation. This peat, however, rests on a bed of sand and clay which appears to have been deposited in its present position by the rush of water which was forced over the Craigs on the opposite side of the river at periods when it was in flood. The great rush of water at this spot over an escarpment of not less than 20 feet must have diminished in later times as the rocky face retreated backwards, allowing the peat, which at that time covered the district to the north, to creep over the sand; and the presence of the latter, in my opinion, will better account for the unstable foundation on which the Abbey is built. Even in later times, when St. Mirren preached to the inhabitants of Strathgryffe, and built them a place of worship, he was doubtless attracted to the place by its surprising beauty; and in still more recent times, Walter, the first Steward, when selecting the spot to found the present church, must have been attracted as much by the beauty of the place as by the legendary traditions of St. Mirren. The water which at present constitutes the impure stream is perhaps not one-fifth of what made up its volume in its palmy days, before so much of it was diverted to supply the south side of Glasgow, and retained in great ponds, was dammed up against times of scarcity, to be afterwards sent down the Clyde in a polluted condition.

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When the water flowed in its pristine beauty over the rugged escarpment which extended right across the present site of the Infirmary, with the Saucel Hill, wooded to the top, for a background, and trees fringing the stream on both sides, the green sward sloping from the church to the river's brink, and the pure water, alive with perch, flounder, trout, salmon, and the pearl-bearing mussel, which was exported to different countries—the scene on a summer Sabbath-day must have been as refreshing to the bodies of the parishioners and pilgrims from distant parts of the country as the truths taught within the walls of the church were grateful to the minds of the worshippers.

Passing further east, we are met by the intrusive dolerite, which appears near the surface in Abbey Street. This rock cannot extend further west on its present level than Bridge Street, as is proved by the underground passage extending between that street and the river. This passage appears to have been constructed entirely in alluvial soil, for the dolerite appears near the surface at the east end of Abbey Street, underlying Thread Street, Bank Street, and Gauze Street, and rising to the surface at Mill Street.*

It appears somewhat peculiar that this rock should form such an abrupt side to the west boundary of Mill Street, and at first I came to the conclusion that it had been faulted; but Mr. Clark informs me that it was quarried about 90 or 100 years ago for building purposes, a fact that accounts for its absence. Several of the houses on the west side of Mill Street have their front walls built on the dolerite, while the back walls are resting on forced earth; and one or two which have been recently built in this position are showing signs of subsidence, which is not to be wondered at. This bed of dolerite extends eastwards until we come to the magnificent opening at the workings in Mill Street

* There was a legend current 50 years ago—long before the passage was discovered—that in the days of Mary Queen of Scots there existed an underground passage which extended from the Abbey to Crookston Castle. But the presence of this bed of intrusive dolerite interposes an insurmountable barrier to the existence or extension of the underground passage much farther eastward than Bridge Street. The late Mr. Semple proved the reputed residence of Mary Stuart at Crookston Castle to be a myth, for he tabulated every day she spent in Scotland, from the day on which she landed at Leith until the day she fled to England, and he could not find one single day on which it was possible for the Queen to have been at Crookston Castle!

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Quarry. It does appear strange that, while strangers coming from distant parts of our own country and from other countries exhibit the greatest interest in the examination of those marvellous surface striations on the rock and the boulders which acted as tools in the production of them, comparatively few of even our intelligent townsmen have ever seen them, although their presence suggests as much to the reflective mind in this country as the Alps suggest to European travellers or the Andes to South American ones.

The section at the quarry consists of—

Surface Soil, - - - -	1 foot 5 inches.
Upper Boulder-clay, - - -	3 to 4 feet.
Lower Boulder-clay, - - -	6 feet 8 inches.
Intrusive bed of Dolerite, - -	25 ,,
Burned Coal, rendered columnar, -	4 inches.
Argillaceous Shale, - -	upwards of 10 feet.

At the foundation of the stalk of the Seedhills Finishing Works the Boulder-clay was found rising to the surface at an angle of about 20 degrees. The sand, shell-bearing clay, and gravel, all lie in their proper order at the same angle. It looks as if the series had formed part of the slope of a hill of which the top had been cut off, the ground being comparatively level for a considerable distance round the spot.

The construction of the common sewer which was recently formed in front of Greenlaw Church, at a depth of 16 feet, started from Glasgow Road in the Boulder-clay which forms the subsoil for the entire distance until the slopes of Greenlaw are reached, when its surface is covered by the entire series of upper deposits. Indeed, this hill appears to consist entirely of, and owes its elevation above the surrounding subsoil of Boulder-clay to, these deposits, which rest in a perfectly horizontal and isolated position.

Proceeding a little further to the east, we come to that interesting section which has been so perfectly exposed by the opening up of Arkleston Tunnel. Before making any statement about this section, I would draw attention to the north bank of the railway, from the bridge over the line west to the signal-box. The weathered limestone stratum in this bank exhibits a richer variety and more abundant quantity of delicate organisms than I have yet seen in any section of these deposits. This section was closed about ten years ago, and has since got a large covering of

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the débris placed over it. But from the exceptional interest of the deposit I think it well worthy of being noted in a paper such as this.

When passing through the railway cutting at Arkleston, we can all see that the section has been faulted upwards at its western extremity to an elevation of not less than 70 feet. The section is a perfect counterpart of the Mill Street Quarry, with this difference—that it has a different elevation and dip. I might also add that the dolerite is not nearly so pure as it is at Mill Street. At the lower part of its western exposure, it has caught up large quantities of the "blaes" in its mass. Large sections of the altered dolerite (or "white horse" of the miner) pervades it in places from top to bottom, while it has caught the upper portion of the coal-bed in pockets at its upper surface. I had considerable difficulty for several years in assigning the various exposures of this dolerite to the same horizon, there being nothing on the upper surface of the Mill Street rock except a few patches of the burned coal where that had been spared by the grinding of the ice-sheet. But within the last year a new stratum was discovered at the east end of the quarry which had just been uncovered, and on examination I found it to consist of an impure limestone, about the same thickness as that which covers the iron pyrites at Arkleston; also, a thin bed of the pyrites, which, although only a very thin seam, goes, I think, to prove that the strata are identical, and that between these two places, about a mile apart, the dolerite has been intruded through the same coal strata. I would also state that the greater purity of the dolerite in the exposure at Mill Street, as also its greater density and compact form, may be due more to differences in the rate of cooling than to variations in the mineral composition of the rock itself.

I have now taken you to the eastern boundary of the Burgh of Paisley. Before closing, however, allow me to make a few observations on its western extremity.

In the neighbourhood of the new spinning mill erected at Ferguslie by Messrs. J. & P. Coats there have been several openings made and bores put down, so that the Surface Geology of this district is better known than it had been previously. The section to which I shall confine my remarks is on the slope of one of those rounded hills to which I have alluded, and immediately to the south of what is known as the Green Road. The rock is

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usually struck at an elevation of from 27 to 30 feet above sea-level, and is generally covered by the Boulder-clay. But in a section a little south of the old Glasgow and Ardrossan Canal, now converted at this place into a reservoir for the mills, there are only 8 inches of broken rock on the top of the bed-rock, the Boulder-clay being quite absent. Above the broken rock there is a deposit of sand and gravel 3 feet 7 inches, and over this we have a bed of fine clay 6 feet 6 inches, which is topped by 1 foot of muddy clay, increasing into a bed of muddy sand 2 feet 6 inches thick. This is covered by a bed of pure sand, 7 feet 6 inches; sandy gravel, 1 foot; gravel, 1 foot 3 inches; sandy clay, 1 foot 6 inches; surface soil, 1 foot 2 inches; the entire section representing 26 feet 11 inches of surface deposits, and being something like what we should expect, with the exception of the missing Boulder-clay.

But 100 feet further south, at an elevation of 6 feet 6 inches above the former section, we have the following, commencing at the surface—

Sandy Surface Soil, - - -	2 feet.
Sand, - - - - -	5 ,, 2 inches.
Sandy Gravel, - - - -	1 foot 6 ,,
Boulder-clay, - - - -	24 feet 8 ,,

You will remark that the five lower members are absent, their place being taken by the Boulder-clay. I have not taken the broken rock into account, as I consider it the remains of the Boulder-clay. Now, you have here eight distinct deposits sharply marked, and occurring at heights now ranging from 30 to 59½ feet above high water. This last section does not show the highest point indicated by these deposits, as behind the chimney-stalk of the spinning mill there is a bed of sand mixed with clay which at an elevation of 73½ feet above sea-level tapers to a point on the face of the Boulder-clay, which rises from below the newer beds and forms the subsoil of the top of the hill several feet higher. This 73½-feet level is, therefore, the highest point at which I have been able to trace the sea in recent geological times in our neighbourhood.

[The author died on 19th February, 1889, in the 57th year of his age, a few weeks after reading this paper at the January Meeting of the Society. See notice in the *Proceedings*, March, 1889.]

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No. X.—The Great Ice Age in the Garnock Valley. By John Smith, Kilwinning. With Four Plates. [Nos. VI. to IX.]

[Read 9th January, 1890.]

The Garnock Valley, situated in the northern division of Ayrshire called Cunningham, is bounded on the W. and N.W. by the range of hills which begin a little to the north of Ardrossan and stretch in a northerly direction for a distance of 11 miles, then wheel round towards the E. and continue nearly to Lochwinnoch. On the E. the valley is bounded by the low ridge which forms the watershed between the Lugton and Glazart Waters, and on the N. by the Lochliboside and Beith hills. Between Kilbirnie and Beith the valley continues in a N.E. direction past Lochwinnoch, Johnstone, and Paisley, the col at Kilbirnie Loch being 94 ft. above sea-level. In the N.E. corner there is another opening through Lochlibo towards Barrhead, between the Lochliboside hills and the high ground E. of Ouplawmoor. In this direction the ground—500 to 725 ft. above sea-level—is lower than on the N.W. side of the valley, but the watershed is higher by some 300 ft. From its peculiar position, defended on its N.W. side and partly on its W. side by hills rising to 1260 and 1710 ft., the cols between which are at no part perhaps less than 1200 ft., except in the narrow pass through which the Largs road runs at Muirhead and Blairpark, where the watershed is about 900 ft., it seemed to present a very favourable field for the study of boulder dispersion, more especially of those boulders whose parent rock is situated somewhere in the Highlands, as this rampart of hills would form to a certain extent a barrier to any ice-sheet approaching the Garnock Valley from a N.W. direction, or, in other words, from the Highlands. Anyone who takes his stand on the high ground to the N.E. of Kilwinning and looks towards the N.W. will understand the full force of these remarks.

This last summer (1889), from the long-continued dry weather, the water in the streams having fallen to an unusually low level, I took the opportunity of examining all their channels with a view of working out not only the foreign but the local boulder dispersion, not forgetting at the same time to note boulders built into fences, lying in fields (precious few now) and on hills, hillsides, and roadsides. The results of the various traverses I made have cer-

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tainly been in the highest degree interesting and instructive, and, without going too minutely into detail in regard to the various boulder records, I have no doubt that they will be of great interest to the student of geology in general and to the glacialist in particular.

Commencing, then, at the lowest reaches of the Garnock where boulders have been found, our first record will be two dolerite blocks about 10 cwts. each, well-rounded, striated, covered with *serpulæ*, *balanæ*, *polyzoa*, and *spirorbis*, and imbedded in sand 26 ft. *below* sea level and 9 ft. above the top of the Boulder-clay. They were got in the sinking of Misk pit, and I may say once for all that these two blocks are the only known ones in the Garnock Valley that to a certainty have been carried by icebergs, with the exception of certain blocks near Smithston House and near the source of Redburn, which will be referred to in their proper places.

The estuary of the Garnock for the first three miles from the sea, ebbing and flowing as it does over the Raised Beach beds of sand and gravel, has no boulders exposed along its surface. The surface beds at Misk are 42 ft. thick, including 7 ft. of Boulder-clay, and are all below sea-level. The fossils from them, collected by myself when Misk pit was being sunk, have been described by Mr. David Robertson in the *Transactions*, vol. v., part 2, and show that the stratified clays and sands on the top of the Boulder-clay belong to the Glacial or Post-tertiary series. On the Bogside side of the estuary are a series of rusty sands and gravels some 20 ft. thick, above sea-level, and belonging to the Raised Beach series of beds, but at this part entirely devoid of organic remains. Opposite Bog farm the estuary first begins to flow on Boulder-clay, which is only seen in the bed of the stream when the tide is low. At this part are a few boulders, of which the following may be noted:—Four specimens of grey porphyrites (15in.); purple porphyrite with grey felspar (2ft.6in.); and *red sandstone with white globular patches (10in.), opposite Bogend; *grey "white horse" (5ft.), 6 feet above river, opposite Nethermains. At Dykehead, near mouth

* Boulders foreign to the valley are marked with an asterisk. Some porphyrites, dolerites, &c., may have been brought from districts at a distance, but it is impossible, for me at least, to distinguish them from blocks belonging to native rocks. I may say that where one measurement is given the boulder is roughly globular or of small size, and where two measurements are given the depth has not been ascertained from the boulder being partially buried.

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of Redburn, a great number of boulders are seen in the river bed, dolerites and anamasites, up to 3ft. diam., a few porphyrites, sandstones, limestones, and some dolerites with green saponite. A fine boulder of greenstone has been "slaughtered" by some vandal boring a deep shot into it, a fragment measuring 7ft. × 6ft.; grey "kingle" (4ft. × 3ft.) with rounded corners. Kingle is a mining term applied to a very hard variety of sandstone. The parent rock may have been rendered hard by having been in contact with a trap dyke or float, or by having been impregnated by certain carbonates (lime, iron, or magnesia). See J. Wallace Young's papers in volume ii. of the *Transactions*. There are not a great many boulders from Dykehead to Kilwinning bridge, but the following may be noted:—Blue crinoidal limestone (4ft. × 3ft.), tabular, with rounded corners; this rock is from a bed some distance above Beith white limestone; greyish "white horse" (3ft.). White horse is a mining term applied to a very light-coloured (sometimes almost white) variety of trap, some specimens containing as much as 10 per cent. of water. Felspar porphyrite with specks of red saponite (2ft.); *grey grit with $\frac{1}{16}$ inch quartz grains and fine horny patches (2ft.2in. × 22in. × 10in.); clayband ironstone (13in.); *mica schist with layers of quartz (15in.); purple felspar (15in.); green porphyrite with light-green felspar (15in.); *greywacke with glassy quartz (16in.); *red sandstone conglomerate with quartz pebbles up to 1in.; crinoidal limestone (3ft.6in. × 3ft.), flat; anamasite with hornblende (5ft.6in. × 2ft.6in.); blue Beith limestone (3ft.6in.) flat. A lot of dolerites, anamasites, limestones, and a few porphyrites (under 3ft.); these are all about Dirrans. Here, and just where the bridge of the Lanarkshire and Ayrshire Railway is being built on the south side of the Garnock, was exposed the bed containing Post-tertiary glacial shells, the found for the piers passing through it. See Mr. David Robertson's paper in *Transactions*, volume v., part 2. Passing while the lade to Small's sawmill was being cleaned, I saw numerous specimens of *Tellina calcarea*, &c., thrown out, proving the extension of the glacial shell-bed in this direction. *Contorted mica schist (11in.) with $\frac{1}{8}$in. quartz grains; porphyrite with white blotches of felspar* (3ft.9in. × 2ft.4in.); *vein-quartz with green patches (12in.); dolerite (3ft.); *mica schist (16 in.).

This brings us to Kilwinning dam, where a large quantity of boulders have been gathered together from the bed of the stream,

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and probably from the fields, to form the dambreast. The most noteworthy are four well-rounded boulders of *Ben Cruachan granite, three of them (10in., 14in., and 16in.); and one (22in. × 14in.); *three contorted schists (14in. to 17in.); *fine-grained grey grit (15in.); *grey grit with $\frac{3}{8}$in. glassy quartz grains (2ft.2in. × 1ft.4in.); *grey grit with $\frac{3}{8}$in. common quartz (2ft.7in. × 14in.); sandstone (20in.); *schist (14in.); amygdaloid (14in.). A little distance below the dam are *fine-grained grey grit (4ft.7in. × 3ft.) flat, which has been blasted; *fine-grained grey grit with $\frac{1}{8}$in. glassy quartz (2ft.6in. × 1ft.4in.); *green schist; *greywacke (12in.); white Carboniferous chert (2ft.3in. × 12in.). Here the Boulder-clay is about 40ft. thick above the river bed, but its base is not seen. Some distance above the dam, and 100 yards below the L. and A. railway bridge, is the largest granite block in the valley—*grey granite, with no large mackles (4ft.6in. × 4ft.), and very well rounded. Near it, *grey grit with $\frac{3}{8}$in. quartz (4ft.9in.), with a little mica and some quartz veins; *grey grit with $\frac{1}{8}$in. milky quartz (2ft.2in. × 19in.); also a lot of dolerites up to 4ft. diam., and a few smaller limestones and sandstones. At and near this bridge are:—grey porphyrite (2ft.6in.); Beith blue limestone (4ft. × 3ft. × 3ft); *contorted mica schist with irregular quartz layers (5ft.9in. × 3ft.4in. × 3ft.); Beith or Auchenskeith blue limestone (5ft. × 3ft.); dolerite (6ft. × 2ft.6in.); greenstone (5ft. × 4ft.); Fergushill Ha' dolerite (5ft. × 2ft.6in. × 1ft.6in.), at foot of Groatholm. Here a section of red, black, and grey alluvial sand and gravel (10ft. thick) is seen on the riverside. Lower Carboniferous limestone *in situ* near G. and S.-W. railway bridge, and in river opposite old kiln; large boulder in centre of river; a few small dolerites and limestones; *? reddish-brown sandstone (6ft. × 4ft.6in.) resting on lower blue Carboniferous limestone *in situ* near Cartleburn; blue Beith limestone at mouth of Cartle Burn (6ft. × 5ft.); another a little smaller. Above Groatholm farm bridge are seen laterite and compact grey ash-beds *in situ*. And below Dalgarvan mill are a few dolerites, some over 4ft., and some smaller porphyrites. From Dalgarvan to Kilkush boulders are very numerous, especially opposite Monkcastle, and Boulder-clay seems to have been pretty thick here before the River Clyde cut its way through it. It seems to be a general rule, although there are exceptions, that where boulders are numerous Boulder-clay has been thick. A lot of dolerite

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boulders are built into Dalgarvan dambreast, some over 4ft. and one over 6ft. *Grey grit (18in.); porphyrite (6ft.6in. × 6ft. × 4ft.); another about the same size; purple felstone *in situ* at Dalgarvan dam; very weathered green dolerite, eaten into cavities, with much pyrite (the cause of weathering) and some biotite (2ft.). Near Dalgarvan old dam is a greenish kingle *in situ*, highly-inclined and dipping S.E.; green dolerite below old dam (5ft. × 4ft.); *contorted schist with contorted quartz layers (4ft.6in. × 3ft.4in.), on east bank of river; dolerite, same as Wee Craig (6ft. × 4ft.3in.); a few smaller porphyrites and white sandstones; *siliceous grit with $\frac{1}{8}$in. quartz (3ft.9in. × 1ft.8in.); dolerite, same as Wee Craig (7ft. × 4ft.6in.); dolerite (4ft.6in. × 4ft.); *close-grained tough greywacke (2ft.6in. × 20in.); anamasites (6ft. × 3ft.6in.); agglomerate, *in situ*, in highly-inclined beds at Dalgarvan old dam; *mica schist (2ft.5in. × 2ft. × 1ft.); *a few vein-quartz pebbles up to 6in.

The Wee Craig. This is a conspicuous boulder of fine-grained dolerite, with black glittering crystals of hornblende, standing in the river near the mouth of Monkcastle Burn (8ft.8in. × 6ft.); *chlorite schist with fine muscovite (19in. × 11in. × 5in.), opposite mouth of Bombo; dolerite with red and green spots (4ft.3in. × 2ft.6in.); limestone (7ft. × 4ft.), flat; *fine-grained green greywacke with $\frac{1}{16}$in. glassy quartz (3ft.2in. × 2ft.6in. × 1ft.4in.); section of bluish Boulder-clay near Bombo mouth, 20ft. high, base not seen; white sandstone (3ft. 6in. × 2ft. 6in. × 1ft. 6in); rolled furnace slag in river gravel; sandstone (4ft. × 2ft.6in.); a few traps near mouth of Caaf. From Caaf Water to near Kilbirnie station the Garnock inclines to the E. side of valley. This appears to be caused by the Caaf, Rye, and Pitcon Waters shoving it over in that direction, as they run with considerable velocity from the hills. Monkcastle escarpment rises to a height of about 200ft. above the Garnock opposite Kilkush, and is a true crag face. A lot of boulders are built into the wall along the side of the Garnock at south side of Dalry. Dalry appears to be situated on a large drum of Boulder-clay, probably 60 or 70ft. thick, and which has a steep face towards the N.E. and a long sloping tail towards the S.W. At the bridge there are a few trap blocks under 4ft., and one limestone. A lot of boulders are built into Biggart's dambreast, mostly dolerites, anamasites, and a few felstones. At Biggart's dam the Boulder-clay is about 30ft. thick, base not seen;

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a few boulders of dolerite, (3ft.); limestone, (3ft.); sandstone (4ft.). On right and left of the Garnock, at Pitcon and Carshead, are large conspicuous drums of Boulder-clay. No Boulder-clay sections from here to Davidshill. A few boulders here and there along the river sides, where they have evidently been brought to protect the banks. The Garnock opposite Hagsthorn passes over the site of a filled-up lake, the bottom of which is at some parts on about a level with present high-water mark, and the deposits filling it are composed of mud, or sandy mud, to a depth of about 80ft. In some parts of this hollow there is not a vestige of Boulder-clay.

At Davidshill 20ft. of Boulder-clay is exposed on each side, with here and there a few blocks of sandstone, limestone, and a few quartz pebbles up to 5in. diam.; *greywacke (2ft.5in. × 14in. × 9in.); a few boulders at mouth of Powgree Burn, near Kilbirnie station; a few opposite Glengarnock houses; bluish porphyrite (6ft. × 4ft.); a few traps below bridge. There are not many boulders from the bridge to Kilbirnie. A short distance above the bridge is a considerable face of Boulder-clay, 20ft. thick, along the east side of the stream. The stones in it are mostly small, only two large ones being exposed—one sandstone and the other a limestone, at 6ft. from top. *Balmaha (?) red sandstone conglomerate (9in.); Boulder-clay (18ft.); only one large boulder, a fine-grained grey limestone. At this point the Garnock bids fair to find its way into Kilbirnie Loch some day, and flow thence to the Clyde. *Greywacke with quartz veins (8in.); *hornblendic felsite (8in.), very hard and well rounded; *Ben Cruachan granite with large felspar mackles; beautifully contorted mica schist (2ft.1in. × 21in. × 9in.). Both of these are close together at the riverside, south end of Kilbirnie. As the above is the last granite I observed in the Garnock, I may say that the height above sea-level is about 120ft., but as the Boulder-clay at this place is 30ft. thick above the stream it has probably been at a higher level. It has again to be remarked that the stones in the Boulder-clay at this point are mostly small.

Between this and the north end of Kilbirnie boulders are not numerous. The following were noted:—A few fine-grained limestones; bluish felstone with green spots (5ft.); a few boulders at first dam, the water being extremely dirty. A trout that could not live, and a large eel in same condition. Kingle (3ft.3in. × 20in.); *hornblendic felsite (4½in.), which may have been brought from

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higher up the river, but foreign to the district. A lot of dirty boulders in second dambreast :—Fine-grained dolerite (5ft. × 4ft.); *quartz with mica (10in.); green dolerite (4ft. × 3ft.6in. × 2ft.) with light-green felspar; limestone composed of small crinoids (3ft.9in. × 2ft.); a few small greywackes; some fine amygdaloids, all the cavities filled with calcite; small bank of Boulder-clay with imbedded block of sandstone *on end* (5ft. × 20in.) (see Plate VI., fig. II.); sandstone (12ft. × 4ft.6in.); sandstone with barite (7in.).

The bed of the river a short distance above Kilbirnie is filled with beautifully clean gravel of large size, but there are few boulders. *Quartz with green patches (6in.); a few smaller ones; a section of muddy peat, 1ft.6in. thick, overlaid by 4ft. of river gravel; purple felstone (3ft. × 2ft.2in.); limestone composed of small crinoids (3ft.); barite (5in.); *fine-grained greywacke (9in. and 11in.); brecciated felstone, cemented with quartz.

This brings us to the third Kilbirnie dam, a beautifully clean one, and quite beyond the influence of civilisation. A yellowish sandstone, *in situ*, below the dam, is the only rock exposed in the bed of Garnock since we left old Dalgarvan dam. From this to the foot of Glen Garnock a great many boulders, all hill blocks belonging to the district, but no foreigners observed. A few may be noted :—Porphyrite with prehnite; amygdaloid with cavities filled with small red stilbites and calcite; porphyrites containing large cavities with yellow calcite, frequent; *two pebbles of milk-white vein-quartz (4in.)—of course foreigners; agglomerate with rounded (5in.) pebbles of porphyrite in a greenish paste; reddish boulder of porphyrite with redder crystals of felspar, and very hard; some felstones, dolerites, and anamasites. None of these boulders were over 5ft. diam.

Glen Garnock is for the most part bounded by perpendicular walls of porphyrite as far as the castle, rising in some parts to a considerable height, and has evidently been cut off *since* the glacial period, the old glen filled with Boulder-clay lying probably a short distance to the N.E. A fine-grained greenish dolerite dyke in glen, about 6ft. wide, cuts through amygdaloid with hollow cavities, and others filled with small red stilbites. A small greenish ash-bed is seen about the middle of the glen, and veins of barite, 2in. to 3in. wide, cut through the porphyrite a short distance below the castle. A little below and at the castle, in river bed, is an agglomerate *in situ*, with well-rounded *stones and boulders* up to 4ft.

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diam. The paste is greenish, and the stones, where exposed, appear all porphyrite. It looks like an ancient Boulder-clay belonging to the period that intervened between the Calciferous sandstones and the base of the Carboniferous limestone, and deserves a visit from interested parties. From the castle to the falls the stream is nearly rock-bound all the way. Only at a few places does the glen open out for a small space, being for the greater part of the distance an old V-shaped glacier gutter. Patches of Boulder-clay are seen here and there lying on the slopes for a distance of 150ft. up. With few exceptions all the boulders are local, and no foreign blocks *or pebbles* were observed in any of the Boulder-clay exposures. The following were observed:—Small boulder with analcite; striæ on the rock in the direction of the glen, a little above castle. Some pieces of barite; *pebbles of vein-quartz, one mile above the castle; greenish ash-beds in the porphyrite; quartzite (12in.), resembling the rock at Muirshields barite mine.

One-and-a-quarter mile above the castle the rock is a soft amygdaloid with calcite-filled cavities containing a few red stilbites. At some places the river has cut below the old glaciated surface into the porphyrite for a distance of 10ft. to 20ft. At one part there is a fine *perpendicular* glaciated face of rock of 10ft., and in the direction of the glen. Another glaciated surface with striæ rather more to the westward. About two miles above the castle a *quartz pebble (1in.); *another further up (2in.). Quartz is getting precious. Large cavities in porphyrite lined with beautiful quartz crystals; amygdaloidal boulder (3ft. diam.); *magnesian limestone (8in. diam.) with numerous veins. There is no magnesian limestone *in situ* in the Garnock Valley. *Light fine-grained very tough greywacke (3ft. diam.), nearly globular; *small quartzite boulder with red jasper, the only one of its kind seen; *magnesian limestone (9in. diam.); *contorted schist (2ft. × 15in.), well rounded and very hard, not far from the mouth of the King's Burn. Thin red ash-bed opposite to where the burn comes in on the left. Rock at the 20ft. falls, reddish porphyrite; a little further up, greenish porphyrite with globular white blotches. A short distance above the 20ft. falls the stream runs in the line of a narrow white claystone dyke. *Two quartz pebbles (2in. and 3in.); soft white claystone dyke, 2ft. wide; agglomerate with 6in. pebbles. The second burn to the left runs in the line of a

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thin dolerite dyke. *Quartzite (8in.). The stream here runs over a slanting fall of 15ft. *Quartz (3in.); a six-sided column of amamasite with pretty sharp angles (2ft. × 8in. diam.), in Boulder-clay; green dyke with pink felspar a little above the mouth of Murchan Burn.

The same dyke crosses Garnock and runs in the line of Murchan Burn for some distance—a beautiful rock. *Small boulder of white porphyrite showing flow-structure, laminated with red jasper and having red crystals of felspar, a very beautiful stone, and the only one of its kind observed. From this part to the large falls the glen is bounded by rocky walls. In some places the rock is purplish in colour with white blotches, from mere specks up to 9in. diam., some of them globular, others very irregular, and it is traversed by a few white claystone dykes. The scenery about the falls is quite highland, and spring flowers are here found blooming late into the summer. Above the falls the river runs through an open moor and so continues to its source in the Hill of Stake, which is 1711 feet high. A few fragments of Highland rocks were got to within 200 feet or so of the top of the hill. A short distance beyond the falls a few veins of hematite and barite are seen crossing the stream.

The Penny Burn joins Garnock estuary 3 miles from the sea. Opposite Todhills it flows over Boulder-clay, the stones in which are covered on top with *Melobesia polymorpha.* Some of the limestones have their upper surfaces all eaten into holes by marine animals, whilst the under surfaces are beautifully glaciated and fixed in the Till. A considerable number of the boulders are of white limestone belonging to the upper part of the Lower Carboniferous limestones. The rocks in this neighbourhood belong to the Upper Coal measures. There are a few boulders of small size:—*greywackes; sandstones; dolerites; and porphyrites; above Broom, grey dolerite *in situ;* * quartz (8in.); * greywacke (11in.); * grey Glenfalloch diorite (5in.). Above Kilwinning and Stevenston road at Castlehill are two conspicuous volcanic agglomerate rocks of Permian age rising to the west side of the burn like two small hills, both shewing very decided crag and tail. (Plate VIII., fig. X.) Further up are a few trap boulders up to 3ft. diam.

Red Burn joins Garnock at Dykehead. It gets its name from the peculiar burnt sienna colour it gives to everything over which it flows. This is caused by the iron compounds dissolved from the

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Post-tertiary sands and gravels of the district. Where there is a very strong run many of the drains in this neighbourhood will only last for about four years before they require to be taken up and relaid. Nor does it matter how steep the drains may be laid. I have seen rhones that were placed *vertically* in a pit shank, where the flow of water must have been very rapid, completely choked with hydrated iron oxide. In the upper part of Redburn in Eglinton policies quartz pebbles are pretty frequent in the stratified sands, and near its source at Sourlie railway is a boulder of anamasite 3ft. in diam. lying imbedded in gravel, which must have been borne to this position—90ft. above sea-level—by floating ice. (Plate IX., fig. XIV.).

Lugton Water from Garnock to Lochlibo. Lugton Water joins the Garnock 1 mile below Kilwinning and 4 miles from the sea, at Dykehead, near where the large quantity of boulders are lying in the river's bed. I have said it appears that lots of boulders may indicate thick Boulder-clay, and the Boulder-clay sections seen above the level of both Garnock and Lugton at this part are rather thin, but that it has once been pretty thick is quite possible. We see at Corsehill that the old 25 feet sea-margin abuts against thick Boulder-clay, and no doubt the Boulder-clay to the south of Kilwinning has suffered greatly from marine denudation when the sea stood at that level.

Near the mouth of Lugton and up as far as Eglinton gardens are a good many boulders. One of the first we meet with, about 50 yards above the bridge, is a * grey granite (3ft. diam.), without large mackles. There are white veins through it projecting slightly on the surface. I suppose we are not now to consider these veins as of a subsequent and distinct formation to the granite, but to be the remains of the mother liquor in which the granite crystallized. Light green dolerite (5ft. × 4ft.); * grit with reddish quartz grains (4ft. × 3ft.); * green grit (2ft.6in. × 2ft. × 9in.); small crinoidal limestone (3ft.6in.); *several quartz pebbles (3in. to 4in.); *fine-grained grey grit (3ft.6in. × 3ft.); Beith blue limestone (5ft.); * sandstone conglomerate with white quartz pebbles 1in. diam. (3ft.); hard yellow sandstone (2ft.6in. × 2ft. × 15in.); another a little rustier. *A good many pieces of fine-grained greywacke in gravel near gardens; *grey granite without mackles opposite west garden wall (20in. × 15in. × 15in.); a lot of boulders of dolerites, anamasites, under 2ft.; small boulder of fine grey rhyolite; a lot of

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small traps, &c., built into dambreasts and along side of stream at Eglinton Castle; *fine-grained grey grit (3ft.6in. × 3ft.3in.) *with edges very little worn*, near bridge above Tournament holm; hard grey sandstone (4ft. × 2ft.6in.); porphyrite with greenish felspar (3ft. × 3ft.); Beith limestone (3ft. × 2ft.6in. × 15in.), tabular; * vein-quartz (11in.); porphyrite, with white blotches, part of a "slaughtered" boulder; *fine-grained bluish grit (9in.); Fergushill Ha' dolerite (20in.); green ash (16in.); "white horse" (12in.); Fereneze porphyrite (9in.) with amygdaloids; *mica schist with much white vein-quartz (2ft. × 18in.), very irregularly striated; *grey grit (14in.); *red sandstone conglomerate with pebbles of white quartz and reddish, greyish, and brown felstone (6in.); *Ben Cruachan granite (18in. × 13in.) below Fergushill House; *yellowish white quartzite; *vein-quartz (9in.). Section of bluish Boulder-clay, 20ft. thick, above stream opposite Fergushill House, all the stones seen in it being small; *mica schist (4ft. × 3ft.), at dam near road; a lot of trap and limestone boulders opposite Saughtrees, all under 2ft.6in.; *fine-grained greenish grit (2ft. 6in.), flat; *greenish grit (9in.); *vein-quartz (3in.); small crinoid limestone (2ft.6in.); porphyrite (2ft.6in.); *vein-quartz (9in. and 6in.); many boulders at old dam, mostly dolerites; porphyrite with white blotches (18in.); *coarse-grained grey granite, no mackles (2ft.6in. diam.); *fine-grained grey grit (14in.); limestone (3ft.); reddish rock with agate (16in.); greyish-green porphyrite with yellowish-green felspar (4ft. × 2ft.6in.); *grey granite (18in.); near G. & S.-W. Ry. bridge; *fine-grained greywacke (16in.); limestone striated *across* (6ft. × 3ft. × 2ft.6in), a little above Snaker's bridge; limestone (3ft.); *vein-quartz (4in.); a good few boulders below Snaker's dam, mostly dolerites. Some intrusive dolerite here about position of Main coal and Raes-road coal.

From Sevenacres to Bullerholes there are not a great many boulders. The following are noteworthy:—Agglomerate, on side of Clonbeith railway, with pebbles of *Lithodendron* limestone; anamasite with hornblende (4ft.6in. × 3ft. × 2ft.); *greenish fine-grained grit (2ft.); Fereneze porphyrite (12in.); fine-grained greenish grit (4ft.6in.), opposite Montgreenan Cottage. A few boulders in stream opposite Clonbeith; and at this part of stream are large flat slabs of extremely hard sandstone, with what appear to be the remains of seaweeds twining in every direction and standing out from the surface in bold relief. Greyish-green por-

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phyrite (4ft. × 2ft.6in.); *granite with reddish felspar (2ft. × 18in.), opposite Clonbeith pit; *grey grit with quartz pebbles up to 6 in. (8in.); *white quartzite with quartz veins (9in.); fine example of Fereneze porphyrite (3ft.) below little pond in policies; *vein-quartz (9in.).

From Bullerholes to Auchentiber the boulders, which are not many, are mostly dolerites with a few limestones and still fewer porphyrites. A greyish variety of Fergushill Ha' dolerite containing analcite, cluthalite, marcasite (9in.), &c.; clayband ironstone (9in.); *a few small grey grits opposite Megswells. Here the Clonbeith limestone crops out at side of stream, and is penetrated by small water-worn fissures—caves in embryo; *grey grit (2ft.6in. × 10in.); *Ben Cruachan granite with 2in. felspar mackles (20in.), at Redwells ford; *coarse grey grit (2ft.); and a few smaller ones; *very fine-grained blue slaty grit (11in.); greenish mass of *Lithodendron fasciculatum* (18in. × 4in.); and a smaller one; *grey grit with some milky quartz (20in.); *green* sandstone (16in.); *blue slaty grit with glassy quartz (14in. × 4in.); limestone (4ft. × 3ft. × 1ft.6in.); *Old Red Sandstone (6in.).

Near Redwells ford bluish Boulder-clay is 15ft. thick above stream; a few small grits between here and Auchentiber; a good few boulders from here up to Waterland bridge, mostly dolerites, but a few limestones and fewer sandstones. The following may be noted:—Dolerite (4ft. × 2ft.6in.; *mica schist (14in.), flat; Fereneze porphyrite (16in.); crinoid limestone (3ft.); crinoid limestone (5ft.6in.), square, tabular; *fine-grained greywacke opposite Thorn (16in.); Beith white limestone (6ft.); *felspar rock, rare (8in.).

At Lugtonridge small quartz pebbles are more numerous than elsewhere in Garnock Valley except on the seashore; *pink quartzite (8in); dolerite opposite Mantrap (4ft. × 3ft.); *grey grit with mica (14in.); **white* grit with glassy quartz (10in.); a lot of dolerites built alongside stream opposite Mantrap; *greenish fine-grained quartzite (10in.); *very fine-grained greywacke (8in.); *mica schist (6in.); Fereneze porphyrite (4ft. × 3ft.); laterite *in situ* in bed of stream opposite Oldhall; crinoid limestone (3ft.6in. × 2ft.); amygdaloidal porphyrite (14in.); *pink quartzite (5in.); *fine-grained green greywacke (10in.); *fine-grained green greywacke with ⅛in. glassy quartz (18in.); Fereneze porphyrite (7in.); *quartz (7in.); *greywacke with ⅛in. glassy quartz (14in. and 16in.); *vein-quartz

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(8in.); grey porphyrite (14in.); a few small greywackes (6in. to 10in.); *grey quartzite with quartz veins (7in.); *grey grit, with white quartz and a little red jasper up to $\frac{5}{8}$in., (10in.); *reddish hornblendic felsite (12in.), near Gree; two Fereneze porphyrites (12in.); *fine-grained green greywacke (14in.); Wee Craig dolerite (7ft. × 4ft.6in.); greenstone *in situ*, with a little felspar, a little below Old Mill; *fine-grained greywacke (10in.); *greywacke with $\frac{3}{8}$in. quartz (20in.); a few smaller ones with finer grains. A 12ft. section of Boulder-clay seen below Beith railway, in which the stones are all small.

We may here vary the record by noting a fine patch of *Sedum acre* in flower, and a little further up another of Monkshood. Fereneze porphyrite (13in.); anamasite dyke, 24 yards wide, at old houses above railway bridge; *grey grit (5ft. × 3ft.9in. × 2ft.) with $\frac{1}{2}$in. quartz pebbles lying on dyke; *grey grit with quartz veins (18in.); *fine-grained greywacke with fine muscovite (13in.); *grey grit with $\frac{1}{4}$in. quartz pebbles (18in.); *grey grit with minute glassy quartz (11in.); *contorted schist (12in.). This brings us to Waterland, where a cutting has been made through rock to drain the loch, of which Lochlibo is the remnant.

Draff Burn joins the Lugton in Eglinton policies. In its course through them not many boulders are to be seen, and all under 2ft. 6in. By Lord Eglinton's instructions the Kingfisher is protected here, and I had the pleasure of seeing one when going along this burn, but woe to the unfortunate Halcyon that ventures out of this sanctum. On leaving the policies there are a few boulders before coming to Sourlie railway:—*Grey grit (16in.); kingle (13in.); dolerite (5ft.4in. × 3ft.10in.); a few smaller, up to 2ft.6in. diam.; *coarse-grained grey grit, only partly seen, at least 8ft. across, about 40 yards above road, the largest of its kind seen, and the largest foreigner in the Garnock Valley; prehnite (5in.); *red sandstone conglomerate (15in.), with quartz pebbles; a few sandstones and some small greenish greywackes; *quartz (6in.); a good few traps between railways. Above G. & S.-W. Ry. few boulders, and these small. Fereneze porphyrites (6in.); a few small grits; **white* grit (10in.).

Bensley Burn joins the Lugton in upper part of Eglinton policies. No boulders as far as wall. Above, blue limestone weathered into hollows (5ft. × 5ft. × 1ft.9in.); a few small boulders between wall and Doura railway; *quartz pebbles frequent; very few and small boulders between Doura and G. & S.-W. Ry.

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Fergushill Burn. Very few boulders in this burn. *Some small grey grits.

Blae Loch Burn joins the Lugton near Mantrap. Not many boulders to be seen along its course; above the road a few traps. The following foreigners were noted:—*Greywacke with $\frac{1}{16}$in. glassy quartz (12in.); *greywacke with $\frac{1}{8}$in. glassy quartz and some milky quartz (18in.); *fine-grained greywacke (2ft.); *vein-quartz (11in.); *greywacke (16in.); thin veins of satin spar, opposite Burnhouse; *quartz (4in.); **white* quartzite (8in.), veined with quartz; *fine-grained greywacke near Beith railway (14in.); *Glenfalloch diorite at Dustyridges (16in.); *fine-grained greywacke (2ft.2in.) at Old Mill; a deep cut made through limestone to partly drain the rock-bound Blae Loch.

Redstone Burn joins Garnock at Kilwinning. In lower part of burn numbers of dolerites, anamasites, and some limestones, up to 3ft. diam.; *some quartz pebbles, up to 4in.; built alongside the burn some West Doura conglomerates, but these not properly boulders. This conglomerate, which is composed of beautifully almond-shaped white quartz pebbles has been largely used in the older part of Kilwinning Abbey, and from thence has found its way into many of the buildings about Kilwinning. I have never found any of this conglomerate as boulders, but this is easily accounted for, as the ground to the S.W. of West Doura, where it crops out, is covered with Post-tertiary beds. As the ice moved in this direction at this part of the valley there is not much likelihood of any being found except in the trifling area exposed by the Penny Burn. A few boulders opposite Bannock:—*Red* kingle (15in.); *some quartz and a few small greywackes; about this part some large drums of Boulder-clay, as Corsehill muir plantation, Bannock, &c.; *actinolite with very large crystals (5in.), the only one of its kind seen; Fereneze porphyrite (5in.).

Goldcraig Burn enters Garnock at head of Kilwinning dam, and in dry weather the water is remarkably clear, owing apparently to the large quantity of lime it holds in solution. It is a small stream; near its mouth the Boulder-clay is about 30ft. thick above stream, the burn here running on it. Not a great many boulders are to be seen, but the following were noted:—Wee Craig dolerites (4ft. × 3ft.); another (3ft.6in. diam.); and one (4ft.6in. diam.), near Dalry old road; white limestone (4ft.6in.), flat; porphyrite with white felspar patches (3ft. diam.) above railway; sandstone below

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Clonbeith limestone *in situ* at Goldcraig; greenstone (3ft × 2ft.6in.); *grey grit with $\frac{1}{8}$in. glassy quartz (20in.); Beith blue limestone (2ft.), tabular; Clonbeith limestone (3ft.3in. × 2ft.3in.); Beith blue limestone (2ft.9in. × 2ft.6in.); *fine-grained grey granite (22in. × 10in. × 10in.) in dyke at Monkredding; red felspar porphyry; *grey grit (18in.); *fine-grained greywacke (7in.).

Rough Burn joins Garnock near Woodgreen farm, and thence to Dalry old road there are a good few boulders, mostly dolerites; limestone (4ft.6in. × 2ft.6in.); *quartz (9in.); *mica schist (8in.); *fine-grained grey granite (18in.); *grey grit with $\frac{1}{8}$in. quartz (5ft. × 2ft.6in.); greenstone (3ft.); another (5ft. × 3ft.6in.); irony sandstone (5ft. × 2ft.3in.); *Ben Cruachan granite (21in. × 18in. × 16in.), about 50 yards below Dalry old road; section of Boulder-clay here 24ft., bottom not seen; Clonbeith limestone (4ft.6in. × 3ft.6in.); purple porphyrite (14in.); not many boulders from Dalry old road to railway; kingle (2ft.); porphyrite with white blotches (2ft.6in.); dolerite (3ft.); a few others about same size. A good few boulders from Flemland to opposite Jameston, mostly dolerites, and a few limestones. At Flemland the burn is carried under a deep cutting in the G. & S.-W. Ry. by three inverted siphons. *Grey grit with amethyst and opaline quartz (8in.); white sandstone *in situ* opposite mound; *grey grit with $\frac{1}{4}$in. quartz (8in.); *grey grit with glassy quartz and a little pyrite; yellowish angular kingle (15in.); *red sandstone conglomerate with 1in. pebbles of quartz (6in.); red felstone (9in.); *mica schist (7in.); section of Boulder-clay, opposite Jameston, 16ft., with some boulders (20in.); Beith blue limestone (2ft.8in. × 2ft.); anamasite (3ft.); a few quartz pebbles.

Auchenskeith Burn joins the Garnock at Groatholm. Here there is a wide depression in the general physiography of the district, owing to the soft ash-beds below the lower limestones having been scooped out by the ice-sheet. At a first glance it looks as if this depression had been cut out by the Garnock, but this is untenable, as the Boulder-clay slopes gently down into the river which has subsequently modified it by partly *filling in* some alluvial deposits. For the first half-mile on leaving the Garnock the burn flows over these deposits, and of course there are no boulders. Opposite Cockenzie are:—*Contorted mica schist (21in.), fragment; *pink quartzite (8in.); *greenish greywacke (14in.); a good few boulders above the Dalry old road; a few

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quartz pebbles. In dyke at railway is a dressed block of Ailsa Craig syenite, which has not been cut from a boulder, but is one of those used as sleepers when the railway was first made. These blocks will no doubt puzzle the geologists and archæologists of the future, having been brought from various parts of the country, and being composed of various rocks, including granite. They are easily known by having two holes bored in them for the purpose of fastening the chair which held the rail. *Well-rounded grey Glenfalloch diorite (12in. × 11in. × 4½in.) opposite Auchenskeith; greenstone (4ft.6in. × 3ft.6in.); some white limestones, not much worn, a few 3ft. diam.; some dolerites and anamasites up to 3ft. diam., opposite Jameston; greenstone (2ft.10in. × 2ft.3in.).

Smithstone Burn joins Garnock near G. & S.-W. Ry. bridge and is a very small stream. We note near Dalry road:—Well-rounded limestone block (6ft. diam.); another rounded Beith blue limestone (8ft. × 6ft.); sub-angular blue limestone (6ft. × 3ft.6in. × 2ft.6in.); other smaller limestones, evidently from the outcrop near mouth of stream; also a few dolerites and anamasites.

Cartle Burn joins Garnock near Cartleburn farm. South of stream and a little above Dalry road the Lower Carboniferous limestone has been mined. On top of old mine is seen a section of both the ground moraine and iceberg Boulder-clays with stratified sand-beds between, the only place in the Garnock Valley where the iceberg Boulder-clay is to be seen. The section is as follows (Plate VIII., fig. IX.):—

Reddish granular quasi-stratified iceberg Boulder-clay, with boulders up to 22in. diam., . .	8 ft.
Yellowish and grey sand with thin layers of clay and coal partings, ...	9½ „
Tough reddish blue Boulder-clay (ground moraine),	4½ „

In the interstratified sand I have not been able to detect a vestige of even a microscopic organism. Opposite the old kiln there is a Blair greenstone (4ft.3in. × 3ft.6in.); limestone (5ft. × 4ft.6in.). A bit of Bavarian lithographic stone was got here, but some green coloured inverted lettering on it prevented us from speculating on the probability of a special small iceberg post having brought it over. A few dolerites and some limestones at upper old quarry; *grey grit with ⅛in. glassy quartz (20in.); *another with ¼in. glassy quartz (9in.), near Gateside.

Dusk Water enters the Garnock at head of Dalgarvan dam. Near

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its mouth is a grey chert (unfossiliferous to the naked eye), (21in. × 14in. × 9in.), rounded a little at the corners, minutely spotted with white all through the mass, the spots changing to red where decomposition has set in; the parent rock is not known to me. A few traps and limestones are seen from the Garnock to railway bridge. A short distance above railway bridge Boulder-clay is 30ft. thick, and occupies bed of stream. For 100 yards up boulders are numerous:—Many dolerites and anamasites, some over 4ft. diam.; limestones and a few sandstones; *fine-grained grey grit; grey porphyrite (2ft. × 14in.); sandstones (4ft. × 2ft.); porphyrite with quartz (15in.); *vein-quartz with sooty cavities (7in.); kingle, well-rounded (8in.); grey porphyrite (2ft.6in.); *grey actinolite rock (8in.), the only one of its kind seen; *a few quartz pebbles and small grits; *grey grit with ⅛in. quartz (15in.); below Kilmarnock railway bridge some deposits of mahogany-coloured clay, a rewash from Boulder-clay; small pot-holes in clay in bed of stream; two limestones (3ft.3in. diam.); many dolerites and anamasites; a few limestones and sandstones from railway to Dalry old road; reddish-brown felstone (2ft.8in. × 2ft.); a great number of dolerites from road to Waterside dam, many over 3ft. diam.; tabular limestone (5ft.6in. × 2ft.6in. × 2ft.); porphyrite with red felspar (3ft.6in. diam.); bluish porphyritic dolerite (6ft. × 3ft.6in.); amygdaloid with egg-shaped cavities in grey paste (20in.), at Waterside, a unique variety. The rock emerges here from under Boulder-clay in the shape of ash-beds. Beith blue limestone (20in.); limestone, tabular (3ft. square); *greywacke (2ft.); *another (20in. × 18in. × 7in.); fine-grained greywacke with a little mica, at dam, and lot of small boulders; agglomerate with rolled pebbles (18in.), a unique variety; *vein-quartz (6in.); reddish-brown felstone porphyry (3ft. diam.); grey porphyrite (6ft. × 2ft.9in. × 2ft.9in.) with pitted surface, at Auchenskeith ford, long axis in direction of ice-movement; green porphyrite (4ft.6in. × 3ft.3in.); reddish-brown porphyrite (6ft. × 4ft.6in. × 3ft.6in.); green dolerite dyke with a little felspar, and slightly amygdaloidal in parts, 25 yds. wide, in Cleaves glen; grey agglomerate (3ft.6in. × 2ft.6in. × 2ft.), where red and green ash-beds crop out in glen; bluish-grey porphyrite (2ft. × 20in. × 20in.); *fine-grained greywacke (2ft.6in. × 20in.); red felstone (4ft. × 3ft.); anamasite (4ft. × 2ft.6in.); very few boulders where limestone comes near the surface at Cleaves Cove; one or two dolerites between first and second falls in Cleaves glen.

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From here to Blair mill only a few small dolerites and felstones; a few dolerites and anamasites from Blair mill to Ravenscraig, some over 3ft. diam.; *fine-grained greywacke at dambreast (2ft.6in.); grey ash-beds, with hard green nodules, below Ravenscraig quarry; grey sandstone (6ft. × 5ft. × 3ft.), angles a little rounded; shaly limestone (6ft. × 6ft. × 3ft.) *Scrophularia Ehrharti* is a common plant from here up. Very few boulders from Ravenscraig up to old dam; *Ben Cruachan granite at old dam (18in. diam.); stream becomes sluggish here, and for a considerable distance is filled with *Equisetum limosum*. Opposite Pencot limestone shales on edge; grey sandstone (6ft. × 4ft.), with sharp angles; *green* limestone (18in.) below Auchenmade kilns; very green (4in.) intrusive beds of dolerite resting on ash *in situ*; lower limestone *in situ* in bed of stream below Dalry road; *greywacke (3ft.); *pink quartzite (3in.); *chlorite schist (3in.); *greywacke with $\frac{1}{16}$in. to $\frac{1}{8}$in. glassy quartz (5ft. × 3ft.6in. × 2ft.6in.), 50 yds. below Auchenmade bridge. From here to Waterside farm stream is sluggish, with few boulders; some small ones a little below Giffen House; a few boulders between road and Barmill railway; grey porphyrite (3ft.6in. × 3ft.) above railway; thin seam of clayband ironstone seen dipping west at Girleston.

No boulders from this to Barmill; stream flowing through a narrow alluvial meadow with many yellow water-lilies. A leaf measured 13½in. × 10½in. with 4½in. cleft, and I note for first time that leaves growing entirely under water are very much crimped, in the manner of a green-kale blade. Above Barmill strata dip steeply. Not many boulders to Hesselhead, mostly dolerites and anamasites, with a few porphyrites. The following may be noted:—*Mica schist (4ft. × 2ft.6in.), below Barmill dam; brown angular kingle (3ft.6in. × 1ft.8in. × 1ft.8in.); *contorted mica schist (14in.); *fine-grained greywacke with quartz veins (2ft.6in. × 1ft.8in.), 6 feet deep in Boulder-clay; *Old Red Sandstone (2in.); near road the strata on edge; dolerite with green glassy crystals (4ft. × 3ft.6in.); *grey grit (9in.); bluish porphyrite (4ft.6in. × 3ft.6in.); another (4ft.6in. × 3ft.); *grey granite in dyke near stream (23in. × 14in.), 200 yds. south of Hesselhead; dolerite with minute saponite (14in.); *grey granite (18in. × 14in.), opposite Hesselhead garden; Hesselhead bridge built on anamasite dyke; *mica quartzite (6in.); *greywacke with $\frac{1}{16}$in. glassy quartz (14in.); *mica schist (12in.); *brown sandstone conglomerate with 1in. pebbles of quartz

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(13in.); lot of limestones with *Lithodendron fasciculatum*; crinoid limestone (4ft.6in. × 3ft.), flat; cutting through anamasite to drain small rock-bound loch at Washingstane; *mica schist (17in.); *a few quartz pebbles up to 3in.; *contorted schist (6in.); *mica schist (6in.).

This brings us to Coldstream, where is found the parent rock of the Wee Craig boulders. *Green greywacke (18in.); *vein-quartz (9in.); stone in clay pot-hole in bed of stream (5in. diam.); *greywacke with $\frac{1}{16}$in. glassy quartz (18in.); *quartz (9in.); *contorted mica schist (10in.); *grey granite in dyke near Townend; *greywacke (18in.); *two greywackes with $\frac{1}{16}$in. glassy quartz (20in.); *grey granite in dyke with 1in. projecting fins (22in. × 13in. × 8in.); *contorted schist (13in.); *fine-grained greywacke (20in.); *grey grit with $\frac{1}{8}$in. quartz (13in.); *a few quartz pebbles opposite Rigfoot; several small Fereneze porphyrites; *quartz and hornblende (18in. × 16in.), very hard and well-rounded, the only one of its kind seen; boulders of Fereneze porphyrite frequent. A little beyond Rigfoot we reach the home of the Fereneze and Lochliboside hills porphyrite, which is easily known, wherever found, by the abundant large crystals of Labrador felspar it contains.

Monkcastle Burn, which joins Garnock about a mile above Dalgarvan, is a small stream with few boulders. The following were noted:—Yellow sandstone (3ft.8in. × 3ft.); anamasite dyke, 6ft. wide; bridge at Dalry road built on one of the upper limestones; greenstones (4ft.6in. × 2ft.6in.), flat; (4ft.6in. × 3ft.6in. × 2ft.6in.); (3ft.8in. × 3ft.6in. × 3ft.); dolerite dyke in glen, 4ft. wide, amygdaloidal in centre. The glen here ends in a *cul de sac*, with 10ft. of ash-beds supporting 30ft. of dolerite, over which the burn falls. Above the falls are:—*Fine-grained greywacke (9in.); Kamehill conglomerate (9in.).

Bombo Burn joins Garnock a little below Kilkush. From the mouth up to where the Blair dolerite is seen *in situ* there are quite a lot of boulders, mostly dolerites. The following may be noted:—Wee Craig rock (4ft. diam.), between railways; upper limestone (6ft.6in.); greenstone (3ft.6in. × 2ft.6in. × 2ft.); dolerite (4ft.6in. × 3ft.); *pink quartzite with some $\frac{1}{8}$in. milky quartz (3ft.6in. × 2ft.6in.), a fine block, and by far the largest of the kind in the Garnock Valley; irony sandstone (5ft.); *vein-quartz (4in.); *greywacke with $\frac{1}{8}$in. glassy quartz; grey sandstone, tabular (7ft. × 7ft.3in.); bluish porphyrite (7ft. × 5ft.). We here note a

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fine patch of the rare *Sedum reflexum* on the side of stream, and on the wall close by, *Asplenium ruta-muraria.* Upper limestone (4ft.3in. × 3ft. × 3ft.); another (6ft.6in.); another (8ft.1in.); Beith blue limestone (1ft.6in.); grey sandstone, tabular (6ft.6in.); shaly blue limestone, tabular (3ft.); grey sandstone, tabular (4ft.); another (9ft.6in.); in wall close by stream *two Ben Cruachan granites (11in. and 14in. diam.); *grey grit (12in.); Carboniferous chert (9in.); *white felspar rock (6in.), the second of its kind seen; *grey grit (⅛in.); quartz (14in.).

At Blair rockery we notice some specimens of fossil plants. One very fine *Lepidodendron* (2ft. diam.) shows the remarkable quadripartite forking of the base, the four principal roots being each forked at 10in. and 12½in. from base of stem. The dolerite here is pillared and very decomposable. Dolerite (4ft. diam.); small dolerite with specks of red saponite; grey *micaceous* fossiliferous limestone, tabular (6ft.); upper limestone (9ft.), flat; grey micaceous limestone (6ft.); grey micaceous limestone in position near gamekeeper's house; upper limestone (5ft.4in.); second upper limestone *in situ* at gamekeeper's house; a good many boulders in Blair policies built along the sides of stream; most probably brought from fields, as the Boulder-clay is thin here. At Lambridden quarry, where the upper Carboniferous limestone has been wrought, *pink quartzite; *quartz with red jasper (8in.).

From Bombo falls to source of stream at south-east of Beith not many boulders, but the following were noted:—*Ben Cruachan granite near branch railway (12in.); laterite (6in.); Wheatyfauld greenstone (3ft.3in.); near Giffen road, dolerite (2ft.3in.); *a few quartz pebbles (3in. to 4in.); *grit with glassy quartz (5in.); *gneiss (2½in.), the only one of its kind observed. *Nasturtium officinale* very common where stream is sluggish. Miocene anamasite trap dyke at Barhill road, bluish and fine-grained, with finer patches. It is largely quarried at Barmill and at Giffen old castle, and is the probable source of many of the boulders of the Garnock Valley. As the Bombo is a self-contained stream with no lateral branches we pass on to Caaf Water.

Caaf Water enters Garnock a mile below Dalry. There are not many boulders from the mouth to Linn Spout, and for 100 yards below Spout scarcely any. Have they been pounded into mud, sand and gravel, as the falls retreated, for these appear to have cut their way back about 106 yards since the glacial epoch? Kamehill con-

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glomerate (14in.); small coarse-grained grit with ½in. quartz pebbles; *purple sandstone; fine boulder of porphyrite near mill-wheel at Linn Spout. The Spout is 35ft. high, and is formed of the upper limestone, which is here very thick and in parts very fossiliferous. A short distance above falls some large blocks of millstone grit have fallen from the cliffs above, one measuring 23ft. × 18ft. × 12ft. This sandstone appears to be very durable, and anyone who wishes to build cyclopean walls will find the material here. A little below Drumcastle bluish Boulder-clay is 30ft. thick, resting on the rock 10ft. above the stream. The boulders are mostly dolerites, porphyrites, and limestones. *Hornstone (4in.); porphyrite (6ft. × 4ft. × 3ft.6in.); and *fine-grained greywacke (4ft. × 3ft. × 2ft.6in.); both resting on sandstone in bed of stream. Proceeding along by the alluvial holms of Caaf not many boulders met with till Giffertland is reached. Numerous pebbles of Kamehill conglomerate; blasted porphyrite with greenish felspar, at mouth of Auldmuir Burn; Howrat white limestone (2ft.6in. × 2ft. × 18in.); *vein-quartz (12in. × 7in. × 5in.); some large porphyrite blocks at Giffertland plantation; porphyrite with glassy felspar (7ft. × 5ft.); red porphyrite (2ft.); *quartzite (2in.).

Above Giffertland plantation is a thick deposit of volcanic ash with large crystals of biotite. In it Mr. Edward Carrick, Dalry, detected *Productus* in fragmentary condition. It also contains quartzite pebbles, charred wood, and *well-rounded* limestone pebbles with crinoid remains. To return to the boulders:—Kingle (5ft. × 2ft. × 18in.); porphyrite (12ft. × 9ft.); *contorted schist (10in.); porphyrite (12ft. × 8ft.), 400 yards below Giffertland mill; *contorted schist (12in.); 20ft. of Boulder-clay with frequent limestone blocks opposite Blackstone; Howrat limestone (3ft. × 2ft.6in. × 12in.); *quartz (4in.); Carboniferous limestone pebble, 300 yards below Birkhead glen, the last limestone seen going up stream; quartzite (9in.), with white quartz and red patches; Kamehill conglomerate (2ft.6in.); *fine-grained greywacke (2ft. × 13in.); contorted schist; greywacke (7ft. × 5ft.), opposite old kiln. This is the second largest foreigner seen, and this variety of rock is known in the district by the expressive and correct name of "Hielan' whin," also "Devils tae breck." The upper white part of lower Carboniferous limestone has been worked here. Red porphyrite (18in.); *contorted schist (2ft. × 2ft. × 18in.), above first glen; *fine-grained greywacke (6in.); *mica schists (3in. and

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9in.); gritty schist (7in.); irony sandstone with *red* quartz pebbles, *parts* of some of the pebbles being white. Boulder-clay above Birkhead glen is 40ft. thick, and of a reddish-brown colour. The Calciferous sandstones further up the glen are now beginning to tell on the colour of the Boulder-clay. The hill porphyrite is first seen *in situ* in Birkhead glen. Porphyrite (7ft.6in. × 6ft. × 3ft.); Kamehill conglomerate (4ft. × 3ft. × 2ft.6in.); near mouth of Drum Burn 20ft. of reddish-brown Boulder-clay; grey porphyrite (6ft. × 6ft.), at mouth of Drum Burn.

From Birkhead to source of the Caaf in Lairdside hill no foreign blocks were noted, but the following local ones may be mentioned:—A lot of small porphyrites and felstones in bed of stream above Birketsteel bridge; the Boulder-clay is 40ft. thick and of reddish-brown colour, and opposite Wardlaw it is the same thickness. Large blocks of Kamehill conglomerate between Brodshaw and Wardlaw. It must be mentioned that this conglomerate, though not so thick as at Kamehill, crops out on opposite side of Caaf valley. Porphyrite (9ft. × 6ft. × 5ft.); reddish Boulder-clay, 20ft. thick, opposite Brodshaw. Here are to be seen sun-cracks, 7in. diam., in Calciferous sandstone.

The *Brodshaw Burn* branches to the east, and in it is seen a good section of part of the Calciferous sandstone series, and the junction with the porphyrites above it. In the Kamehill conglomerate, which has been long used for millstones, the pebbles are nearly all of beautiful white quartz up to 3in. diam. There are also a few light-pink-coloured quartzites. We now come to Lairdside hill, where the Caaf has its source. This hill is of dolerite, has a steep face to the north-west, and a long gentle slope to the south-east, 15° magnetic.

Munnock Burn runs into the Caaf at Drumcastle dam; *Old Red conglomerate. Not many boulders till Caddle is reached, where there are a number of dolerites and porphyrites:—*mica schist (18in.); *red* kingle (8in.); *grit (9in.); *two mica schists (10in. and 11in.); Kamehill conglomerate (21in.); at Munnock dam are a lot of small *greywackes; two porphyrites with agate; *quartz (6in.); *contorted mica schist (3in.); *vein-quartz with mica (7in. and 13in.); *fine-grained greywacke and contorted schist (7in.); at Munnock 1in. vein of barite *in situ* in purple ash; purple Calciferous sandstone dipping E.; Kamehill conglomerate (20in.); a quarter of a mile below Gill farm Calciferous sandstone dips

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S.E. at 40°. Near Gill farm some Kamehill boulders (12in.); porphyrite (4ft.6in. × 3ft. × 2ft.); and near source a Kamehill (15in.).

Auldmuir Burn joins Caaf at Giffertland. Not many boulders are seen in its course, but some porphyrites near lower part. The following were noted:—Porphyrite (8ft. diam.); strata on edge and over it at Giffertland; porphyrite (7in. diam.); Kamehill conglomerate (20in.); red and green ash-beds and agglomerate below Auldmuir; above Auldmuir black shale dipping S. at 40°; *red jasper (4in.), the only one of its kind seen; *some vein-quartz (2in. to 4in.), part of which may be from Kamehill conglomerate.

Drum Burn joins Caaf a quarter of a mile below Birketsteel bridge; not many boulders to be seen in it; greenish porphyrite (7ft. × 5ft. × 4ft.); *contorted schist near small waterfall opposite Birket; porphyrite (5ft.); two large Kamehill conglomerates, only partly seen; another opposite Knockendon (4ft. × 2ft.4in.); sandstone *in situ* with quartz pebbles and thin vein of crystallised barite; burn running on reddish Boulder-clay opposite Knockendon. Kamehill conglomerate (5ft. × 4ft. × 3ft.); mass of sandstone, 15ft. long, possibly not a boulder, with two sets of striæ on upper face and nearly at right angles to one another, but neither of them in long direction of stone; laterite *in situ* in bed of stream; amygdaloidal porphyrite (3ft.); porphyrite (4ft.); reddish Boulder-clay, 20ft. thick. To west of burn near its source is a great hollow, like an amphitheatre, scooped out of the side of Caldron hill, and probably the work of ice.

Drumside Burn joins Drum Burn half-a-mile from its mouth. *Contorted greywacke (5ft. × 5ft.); *greywacke (18in.); quite a lot of Kamehill conglomerates on hillside near source.

Potyan Burn joins Garnock near south end of Dalry. Not many boulders observed along this small stream, and those for the most part local. At Brodlie bluish Boulder-clay, 7ft. thick; *greenish grit (8in.); small boulder of grey mica trap (?); some small sandstone boulders at Fleshwood.

Rye Water joins Garnock half-a-mile N.E. of Dalry. A few quartz pebbles below Stock bridge. Few boulders seen till Drakemyre:—red porphyrite pebble opposite Bogs (5in.); at Drakemyre a few local boulders, over 3ft. diam. From Drakemyre to Camphill boulders are numerous, which would seem to indicate that Rye glen had been pretty well filled up with Boulder-clay, the greater

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part of which has been washed away:—round porphyrite above Dogertland (5ft. diam.); *grit at Ryefield old mill ruins (4in.). Small block of *Lithodendron junceum* in bed of stream; sides worn smooth, but corallites projecting $\frac{1}{8}$in. above surface, which would seem to indicate that sand and gravel carried down by water act as abrading agents only at and near the sides of limestone boulders, whilst acids in the water act on all exposed surfaces. Large flat piece of blackband ironstone; *quartz (2in.); all the quartz pebbles in Rye are likely to be foreigners; porphyrite boulder with prehnite; porphyrite boulder with quartz crystal in cavity; porphyrite boulder with chalcedony, stilbite, and quartz crystals; porphyrite boulder with agate; Dalry blackband ironstone cropping out in Hindog glen; *quartz (3in.); porphyrite with chalcedony; kingle (5in.).

No sandstone boulders seen in Rye Water above Hindog; from Hindog glen up to the source the rocks all belong to porphyrite series; clayband ironstone boulders above Cunningham Baidland footbridge. The section in glen near this will be found described by the late R. A. Skipsey, in *Transactions*, vol. ii., page 248. Where the glen is steep and rock-bound there are no boulders. They seem to have been carried down by floods, and left at the nearest open parts. *Chlorite schist (5in.); Boulder-clay, 50ft. thick, with many limestone blocks; limestone (5ft. × 2ft.6in.); another (2ft. 6in.); another (7ft. × 3ft.); Boulder-clay, 40ft. thick, opposite Greenhill; limestone (2ft. diam.); limestone (5ft. × 3ft.) with *pebbles* of amygdaloid and felstone, opposite Howrat. This block is probably from the outcrop N.W. of Auchenbon, and would seem to indicate that when the lower Carboniferous limestone was being deposited part of the hills to the north were above or near sea-level. I do not know of any other instance of hill pebbles having been got in this limestone. Below Haining, part of river gravel converted into conglomerate; barite (3in.); *well-rounded grey quartzite (20in.); numerous large boulders of porphyrite; *Lithodendron* limestone (18in.), the last limestone boulder met with in the Rye Water; a section of the Boulder-clay below Haining, 30ft. thick, with boulder near the top (4ft. diam.); all the rest small; *quartz (3in.); brownish Boulder-clay at Camphill, 30ft. From Largs road to source of the Rye in Irish Law very few boulders; glaciated surface below Howcraig in line of glen, which is narrow here; *three quartz pebbles (2in. and 3in.); basalt

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(18in.); Boulder-clay near junction with small stream, 20ft. thick; above this stream runs over reddish porphyrite, with agglomerate and felstone near the source.

South Burn joins Rye 1½ miles above Cunningham Baidland, and its whole course is over the hill porphyrites, with here and there Boulder-clay for its bed. Few boulders in it, and all hill blocks. No foreigners observed, not even a quartz pebble. Near road a cavity in porphyrite *in situ*, containing beautifully clear crystallised barite; two red porphyrites (20in.); Boulder-clay on north side, 30ft.; on rock opposite Plann, 15ft.; reddish porphyrite (8in.); striæ, 18° S.W. (mag.), near source.

North Burn joins the Rye opposite Howrat castle hill. Boulders not numerous, no foreign ones observed but one *quartz pebble. Near mouth grey porphyrite seen *in situ*. Dark porphyrite (4ft.6in. × 4ft. × 3ft.); red-bedded porphyrite dipping up stream at about 45°, above and below water catch. *Quartz (1in.); Boulder-clay, 20ft, ½-mile above Haining, stones in it all small; red porphyrite (16in.); bluish porphyrite with green felspar (9ft. × 5ft.); two others a little smaller; Boulder-clay, 30ft., stones all small; red porphyrite (17in.); Boulder-clay, 24ft., stones small; Boulder-clay, 20ft., stones small; Boulder-clay, 30ft., with porphyrite (4ft. × 3ft.) at 6ft. above burn; porphyrite with agate (3ft. × 1ft.6in.); striæ N.W. to S.E.; grey-blotched porphyrite (6ft. × 6ft. × 5ft.6in.) at irony spring, side of stream; several irony springs in bed of stream; bluish porphyrite with greenish felspar *in situ* at Blae Loch; good many boulders in North Burn, few towards source; all the Boulder-clay on north side of stream, the reason appearing to be that the burn began at tail end of Boulder-clay and is working its way northwards.

Routen Burn.—The *Rout dane* Burn joins the Rye near to Camphill. At Largs road greyish porphyrite, with little felspar and a few patches of green saponite, *in situ*, weathering to a purplish colour; some agglomerate boulders composed of fragments of red felspar porphyry; *quartzite (3in.); *quartz (3in.); *mica schist (1½in.)—all a little above Largs road; *quartz (1in.); *honey-coloured hornstone (4in.); *mica schist (5in.); boulders of reddish porphyrite frequent; *three quartz pebbles (2in. to 3in.); barite (3in.); green ash *in situ*, with veins of calcite, some solid and red; *greenish quartzite (3in.); *quartz (4in.); *greywacke (4in.). Where the bed is steep and rocky the Boulder-clay is only 5ft. or

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6ft. thick, and 20ft. to 30ft. above stream; where the gradient flattens the Boulder-clay is 12ft. thick. Barite (3in.); *quartz (4in.); finely-striated surface in bed of stream, striæ pointing to valley; *coarse-grained grit (12in.), about 900ft. above sea level; *quartz (3in.); barite (3in.); Boulder-clay, 24ft., with small hill blocks; *quartzite (5in.); barite (7in.); Boulder-clay, 20in., stones all small; glacial striæ pointing to valley.

Pitcon Burn enters Garnock 1 mile above Dalry. Large bank of gravel at mouth of burn, mostly of sandstone, shale, limestone, and hill rocks. Stream flows for ½ mile over filled-up bed of old lake, and no boulders seen till Borestone is reached. Porphyrite with very red vermilion felspar above Borestone Bridge; a few porphyrites beside it; limestone (2ft.6in.); Boulder-clay, 24ft., opposite Hagsthorn; bluish kingle (18in.); Boulder-clay, 20ft., on 15ft. of rock; *quartzite with quartz veins (8in.); red porphyrite opposite Langside (11in.); well-rounded kingle (3ft.6in. × 3ft. × 2ft.6in.); *quartz (2in.); porphyrite (5ft. diam.), at old ironstone kiln in Swinlees glen; two others about same size; porphyrite (4ft.6in. × 3ft. × 3ft.), a little above junction with Gowkhouse Burn; porphyrite (6ft. × 4ft. × 4ft.); two others a little smaller; kingle (12in.). Lower limestone crops out a short distance above junction with Gowkhouse Burn, and many large hill blocks opposite Howrat; barite (5in.); Boulder-clay (30ft.), opposite Howrat; *grit (5in.); green and red ash-beds *in situ;* banded felstone, mostly hid; large block of limestone, like an outcrop, lying across stream a little above Howrat; Boulder-clay, 30ft.; sulphate of lime (3in.); some large boulders in the clay on both sides of burn. Large number of porphyrite boulders 60 yards below Largs road, one measuring 13ft. diam. is probably the largest in Garnock Valley; many large limestone boulders below Largs road; grey ash *in situ,* with thin veins of satin spar; grey porphyrite *in situ* 300 yards above Largs road; limestone (2ft. diam.); grey perlite (4in. and 3in.), unique; *quartzite with vein-quartz (5in.); radiated spherulite, only one of its kind seen (2in.); *quartz (1½in. and 3in.), above old road.

Gowkhouse Burn joins Pitcon Burn at head of Swinlees glen. A little above junction Dalry clayband ironstone (13in. thick) crops out. No foreign and not many local boulders observed in this stream. Lower limestone crops out near Connelston at Largs road; some distance above, thin veins of steatite in trap tuff; limestone

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(4ft. × 8in.) 450 yds. below old hill road; and limestone (2ft.), last limestone boulder seen; Boulder-clay, 24ft., 400 yds. below old road; grey tuff with 12ft. of overlying Boulder-clay, above road; quartz pebble 300 yds. above old road.

Powgree Burn joins Garnock shortly below Kilbirnie station, having its source 1½ miles N.E. of Beith. The following boulders noted:—Blotched porphyrite (4ft.6in. × 2ft.6in.); dolerite (4ft.6in.), above Kilbirnie station; near old mill in glen waterfall of about 30ft.; in glen limestone composed entirely of small crinoid remains, and of which so many boulders are already noted. It is well exposed in Gurdy cutting of the Kilbirnie Railway opposite. Sandstone (5ft. × 3ft.); syncline in glen above Dalry road; anamasite (5ft.6in. × 2ft.); clayband ironstone, 7½in. thick, *in situ;* large dolerite dyke opposite Roughwood; a good few boulders between Kilbirnie and Beith Railway, mostly dolerites; porphyrites and a few limestones; dolerite column as boulder, with angles very little worn (5ft.6in. × 3ft.); limestone (4ft.3in. × 4ft.); *fine-grained greywacke (10in.); greenstone (4ft.6in. × 3ft.); crinoid limestone, sub-angular (6ft. × 2ft.6in.); a few whinstones from Beith Railway to Gateside; *fine-grained greywacke (16in.); Lower Carboniferous limestone *in situ*, opposite Spears' Institute; *quartz (4in.); two anamasites (3ft. diam.); white sandstone (20in.); *fine-grained greywacke (20in.); greywacke with $\frac{1}{16}$in. glassy quartz (4ft. × 20in. × 12in.), opposite Gateside; a few traps between Gateside and source (under 3ft.); *grey grit with ¼in. milky quartz (3ft. diam.), opposite Langside, 370ft. above sea-level.

Puduff Burn joins Garnock about middle of Kilbirnie. From mouth to Largs road not many boulders. Near Kilbirnie bluish porphyrites (3ft. × 3ft. × 2ft.9in.); dark grey porphyrite (5ft. diam.); *coarse red sandstone with some white quartz pebbles (22in. × 20in. × 13in.); *fine-grained greywacke (22in. × 12in.), 100 yds. above Kilbirnie; *quartz grit (2ft. × 16in.), 40 yds. below Largs road. From Largs road to the large fault which brings up the hill porphyrites from beneath the limestones there are a good many boulders, all hill blocks with the exceptions noted. Some distance above Largs road a cliff 40ft. high, with many open fissures in limestone near the top; and above this the stream, in dry weather, runs in these fissures underground. *Quartz (2in.); small waterfall (10ft.); some distance above, long section of carboniferous shale with numerous examples of *Productus giganteus*

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in natural position; *reddish hornblendic felsite, well-rounded (7in.), scarce; *another (15in.); Boulder-clay, 20ft.; fault brings porphyrites up hill; waterfall of a series of steps (40ft.); further up green porphyrite dyke with pink felspar, weathering yellow; porphyrite (12ft. × 6ft.); green dolerite (2ft.9in. × 20in.); barite (5in.), 30 yds. below 20ft. waterfall; above this a few hill blocks.

Pundevan Burn flows nearly parallel to Garnock and joins it at north end of Kilbirnie. Near mouth number of dolerites, porphyrites, and felstones; and from here up to Dobbie's Cottage a good many boulders; dolerite (4ft.6in. × 4ft.); *quartz with green patches (4in.); clayband ironstone *in situ* in glen (12in.); *quartzite (7in.); porphyrite (7ft. × 5ft.); lower limestone crops out a little south of Holehouse; *contorted mica schist (4in.); a short way above limestone outcrop are agglomerate and ash-beds with well-rounded felstone boulders imbedded; the three largest measure 1ft.6in., 2ft.3in., and 3ft. diam.; purple ash *in situ*, with small calcite and barite veins; waterfall over 12ft. of purple porphyrite; *grey grit (8in.); felstone porphyry (16in.); barite (4in.); very little Boulder-clay seen along banks and only near the lower part of stream.

Surge Burn enters Garnock 4 miles above Kilbirnie. Not a great many boulders seen, but the following noted:—near mouth bedded porphyrite dipping steeply in direction of stream; *quartz (2in.); barite (4in. × 8in.); massive red porphyrite *in situ*, probably one of the sources of many of the red porphyrite boulders; Boulder-clay, 30ft., on rock, stones mostly small and all local; barite (4in. and 15in.); quartzite from walls of barite veins (?) at Muirshields; barite (10in.); red porphyrite *in situ*; red felstone *in situ*; *three quartz (2in. and 3in.); Boulder-clay, 10ft., on rock; barite (3in. and 6in.); greywacke (8in.); Boulder-clay, nearly all stones, with very little clay; barite (9in.); *quartz (1in.); barite (15in. × 13in. × 6in.), the largest barite seen, and probably from Muirshields; Boulder-clay, 20ft; few blocks from here to source.

Murchan Burn joins Garnock a short distance below the falls. In lower part some good sections of white claystone, and other dykes to be seen, also sections of rhyolites and tuff beds. About 200ft. from top of Misty Law, a felstone hill which is 1663ft. high, a *quartzite (4in.) seen, and not far from the top *three quartz pebbles.

Besides the above boulders in the beds and along the banks of

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the streams in the Garnock Valley, a great number of others were noted in dykes, railway cuttings, and along roadsides; but I shall only note a few of them foreign to the district. At Redstone, near Kilwinning, *mica schist fragment (16in.); *contorted schist fragment (17in.); at Fergushill, mica schist (2ft.6in. × 2ft.); in dykes near Torrenyard, *several grey grits up to 18in.; *fragment of fine-grained grey granite; at Snakers sandstone quarry, *chlorite schist (9in.); *greywacke (4in.); old red sandstone (2in.); *quartz pebbles up to 3in. At Lissens, *granite with pink and white felspar, hornblende, and a little quartz (12in. diam.); *contorted schist (18in.); *greywacke (15in.); *quartzite (5in.) quartz (4in.); *greywacke with $\frac{1}{16}$in. glassy quartz (2ft.6in. × 2ft. × 10in.). In dykes at Auchentiber, *twelve greywackes, up to 2ft.2in.; *two pink quartzites (6in.); *several quartz pebbles, one 18in. diam., and the largest piece of vein-quartz seen; *contorted mica schist (6in.); *milk quartzite with mealy grains; *red sandstone conglomerate (9in.); *Ben Cruachan granite (9in.) fragment; *bluish grit (10in. and 14in.); *fine-grained grey granite (13in. diam.) Drumbue farm, near Kilbirnie junction, *pink quartzite (8in.); Gatend farm, *two greywackes (20in.); grey grit (20in.); *quartz (12in.); *fine-grained grey granite (10in.) At South Bar farm, *granite with yellow and green felspar (12in. × 9in. × 3½in.) At corner of farm-steading, *grey granite with dark patches (2ft. 7in. × 19in. × 9in.), 360 feet above sea-level.

When examining the boulders in this district I asked a farmer if he had ever seen any granite lying about his fields. After thinking a little he said, "Na! na! couldna say; there micht be a daunnerin' yin!" Looking at me for a little trying to knock a chip off a hard boulder, he remarked, "Ye'll be in the heidstane line?" At Barmill, in dyke, *grey grit with ½in. quartz (12in.); *Ben Cruachan granite (15in. × 5in.). These last ones are extra thin for granite boulders in this district, which are generally pretty round. At Mantrap, *fine-grained greywacke (4ft.6in. × 3ft.3in.) with flat surface; *fine-grained greywacke (19in.); *a schist with alternate white and dark green bands (16in.), the only one of its kind seen; *greywacke (12in.).

Near Kilbirnie junction on railway banks, *grey granite (7in.); *Ben Cruachan granite (2ft. × 1ft.6in. × 12in.) with dark patches. Cutting at Barmill railway, near Highgate, *greywacke 5ft. from top of Boulder-clay (3ft.4in. diam.); Boulder-clay reddish brown;

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*Glenfalloch diorite, (17in. × 13in. × 6in.); at Wester Highgate, *Glenfalloch diorite (15in. × 12in. × 6in.) Both of these boulders are exceedingly well rounded, and so they may. At Middleton, *Old Red Sandstone (9in.); *Ben Cruachan granite (11in. diam.); North Biggart, *grey grit (22in.). At Giffen, *fine-grained greywacke (20in.); at Tandlehill, *some small grey grits. At Raw, *brown conglomerate (9in.); schist with ⅛in. garnets. At Hesselhead, *mica schist (20in.); *Ben Cruachan granite (10in. diam.). At Davidshill road-end, *greenish greywacke (3ft.9in. × 2ft.10in.), 230 feet above sea. At Cockenzie, *grey grit (2ft. × 15in. × 8in.); *granite fragment (12in.); *chlorite schist (8in.). Near Dalgarvan, *quartz (11in. × 6in.). At Laigh Smithston *a few small grits. At Monkcastle, *reddish hornblendic felsite. Near Caddel, *contorted schist (11in.); *greenish greywacke (9in.). At Birkhead, west of Dalry, cavity in porphyrite boulder lined with agate and amethyst crystals—boulder probably from somewhere about Baidland hill—the only amethysts observed. At Blair, *greywacke (2ft. × 18in. × 15in.); *another (20in. × 20in. × 8in.). At Gooseloan, *Ben Cruachan granite (2ft. diam.), the only granite block seen imbedded in the Boulder-clay. At Auchenskeith, *a "massacred" Ben Cruachan granite; *greywacke (14in.); mica schist (10in.); kingle (18in.); **green* kingle (18in.); *Glenfalloch diorite (12in. × 11in. × 4½in.). At Bowertrapping, *purple jasper veined with white agate (5in.), the only one of its kind seen. At Fairlie Bog, in railway cutting, *green grit (2ft.9in. × 2ft.). At Woodside, in middle of road, *large boulder of grey grit partly seen. At Weirstone, near Kilwinning, *Ben Cruachan granite (9in.). At Outer Airdoch, *granite with pink felspar (8in.).

From the above enumeration of the Garnock Valley boulders it will be seen that whilst the local ones are numerous, except in the extreme west, they all indicate a dispersion from a north-east source, agreeing, in this respect, with the observed striæ on the rock surfaces. Foreign boulders are much less frequent, and from their mineral characters point to the districts lying between Loch Lomond and Loch Fyne, Glenfalloch, and even so far north as Ben Cruachan, as their native homes, to which, like M'Crimmon, the Highland piper, they "shall never return."

To have come direct from those districts the ice which brought them must have travelled over the high rampart of hills, which, as we have already seen, shuts in the Garnock Valley on its N.W.

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side. That some of the ice actually surmounted this rocky rampart I think we have clear evidence of in the Highland blocks observed, *few* as they are, in the higher reaches of the Garnock, Surge, and Routenburn streams. But this could only have happened at the period of the most intense glaciation, when the ice was perhaps not less than 2000ft. thick in the valley of the lower Clyde, and when it may have been much more. We have seen that west of the Garnock erratics from a Highland source are extremely few, whilst on the east side they are comparatively numerous. For instance, west of the Garnock not a single granite block was noted, and in the bed of the Garnock itself only six blocks were counted, whilst east of the river thirty-one granite boulders were catalogued. This fact, together with the striæ observed on the underlying rock surfaces, clearly shows that the stream of Highland erratics entered the Garnock Valley from a N.E. direction, or from one at right angles to that from whence they came.

This latter statement may at first sight seem not a little startling. If we glance at sheet 30 of the 1-in. Geological Survey map we shall see that in the neighbourhood of Kilmalcolm, north of the higher reaches of the Garnock, the glacial arrows, showing the direction of the striæ, all point up the Clyde valley, and look as if they were flying for Paisley. As was first observed by Mr. D. Bell and Professor J. Geikie, the Highland ice did not all find a passage by the Firth of Clyde, and was forced to make its way *up* the Clyde valley, where it was met by the Clydesdale ice near Glasgow, and turned by Paisley and Barrhead in a S.W. direction into the valley of the Garnock; and the position of the Highland boulders in this valley singularly corroborates the observed evidence of the striæ. That the great bulk of the Boulder-clay here is of true ground moraine origin has been already, I think, clearly shown. The only evidence we have of iceberg Boulder-clay being in the lower part of the valley, and at no higher level than 60ft. above the level of the sea, although in the Ardrossan district, not far off, it is found somewhat higher. It might be argued that when the sea stood at a much higher level, 510 feet, when the Airdrie glacial shell-bed was deposited, much of the Boulder-clay might have been deposited from icebergs, and subsequently have been washed away as the sea retreated. Had this been the case, we ought to expect deposits of sand and gravel containing boulders

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lying on the top of the true old Boulder-clay. But except in the low-lying districts near Kilwinning, which have been subjected to marine denudation, deposits of this sort were nowhere observed, neither any accumulations of boulders which could not be accounted for by the removal by river denudation of the old ground moraine in which they had at one time been imbedded. The condition of the boulders themselves, too, shows they have not been exposed for a length of time to the action of the atmosphere. The granite blocks, from what we observe on hills built up of that rock, we might expect to have found in a decomposed state had they been long exposed to the action of the weather, are singularly solid, and it is with difficulty, with few exceptions, that a fragment can be detached from them with an ordinary geological hammer.

Under the great ice-sheet the ground moraine, together with the lower part of the ice, from the friction caused by the stones and boulders grating against one another, and on the rock-surfaces over which they were being driven, must have been alternately freezing and thawing, and this may account for the curious veins of sand we sometimes see in the Boulder-clay. It is interesting to note how the ice quarried the material with which to form the ground moraine. Portions of soft shales were crushed up and the clay and stones forced underneath them, then drawn out into long black strings, as was seen in the cutting of the Lanarkshire and Ayrshire Railway at Lissens. (Plate VII., fig. V.) Soft sandstones were first crushed into brecciated material, then trailed along, the fragments becoming rounder and rounder, smaller and smaller, till a band was formed beneath the Boulder-clay almost like a stratified bed, and requiring some care to distinguish it from one. (Plate VI., fig. III.) This is often seen when the Boulder-clay is being removed from the top of sandstone at quarries N.E. of Kilwinning. Where the sandstone is of a firmer nature, and crops out in the direction in which the ice was moving, the blocks were detached purely by friction. We first see a block *started* from its parent bed, with a portion of fine clay about the thickness of a knife blade occupying the joint. The block before it will perhaps have moved half-an-inch, the one before that still a little further, till we have a whole fleet of them, all at varying distances apart, and whose onward progress was only stopped by the breaking down of the machine that set them in motion. (Plate VI., fig. I.) Once a block had been friction-quarried and fairly started on its

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way it never seems to have travelled as quickly as the clay and stones which surrounded it, the stones in their turn not travelling so quickly as the clay.

From descriptions we often read, one would think that the stones and boulders were all striated by being rubbed against the rock-surfaces over which they travelled; but though they must again and again have been brought into contact with the rock-surfaces by a sort of vertical gyratory motion of the whole boulders and clay, especially those brought from long distances, still the clay would act by friction on the stones, and both on the boulders, so that in such a way they would become striated to a certain extent. It appears to have been a sort of understood arrangement that "if you claw me I'll claw you." The fact of the whole deposit having undergone this kind of motion is proved by the great uniformity in the whole mass where it passes over rocks of firm consistency. Had this not been the case we should have found it banded of all shades of colour, the lowest band taking the shade of the latest rock over which it passed. But colour-banding is found to be very local and confined to patches of the Till where the underlying rocks are soft and easily quarried. The bottom part of the ice would move faster than the surface clay, and it again quicker than the rest of the clay—that at bottom for the time being moving slowest of all from the greater friction it would have to undergo.

Boulders have been moved along with a sliding-rolling motion, and long boulders have constantly gone "head over heels." They have never moved with a side or "row chow" motion, which is proved by the fact that they are found at all angles in the clay, and even standing in a vertical position (Plate VI., fig. II.), and they are striated longways generally, although there are a few exceptions to the rule. This could not have been the case if they had moved sideways, or even have been hauled along in a uniform "end on" direction. Another strong argument in favour of the deposit having been thoroughly mixed in the way indicated, and under immense pressure, is the fact of its extreme toughness—a man with a pick being scarcely able to remove a larger bit at a time than the size of one's hand.

Wherever striæ were observed in steep-sided glens, such as that of the Garnock where the cross section is V-shaped, it was always seen to be in the direction of the glen, whilst the glaciated surfaces

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of the rocks on the moors adjoining perhaps pointed in a different direction. This might be ascribed to a subsequent local glacier, but I think not. I am inclined to believe that the ice and ground-moraine always moved in the line of such glens, and that the ice-sheet went sheer over the top of them independently of their direction. This may not necessarily have prevented such glens from receiving foreign blocks which, passing either along or across its direction, would have a tendency to *burn* into the ice that filled the glen and be deposited in it. Where glens are wide and open the case would be altogether different, the *whole* of the ice-sheet moving slantwise or even directly across them, but no doubt influenced more or less by the slope of the ground, as we see it has been everywhere.

There are in the Garnock Valley some bold glacial escarpments. That near Barmill and Giffen castle, formed by a wide trap dyke already noticed, which extends for a length of 2½ miles, has received the full force of the ice grinding over it from N.E., and makes a considerable figure in the landscape, having considerably protected the strata to the south. The Blair and Giffen dolerite escarpment runs for a distance of 3½ miles, and looks like a line of old sea-cliffs. It received the ice in a more slanting direction than the one already mentioned. Monkcastle and Tower are also conspicuous glacial escarpments, the former rising 260 feet above the bottom of the valley.

Amongst the Dalry and Kilbirnie hills the *roches moutonnées* are to be reckoned by the score, and all give evidence of the direction and intensity of the great ice movement. Before the advent of the glacial epoch the hills in this district no doubt presented a very different appearance from what they now do, being in all likelihood much higher and more pointed, and it is not unlikely that the cones of the old Miocene volcanoes, of which we now find only the "necks," then "towered to the sky." But all this is changed, and the hills are "sow-backed," with strong "crag and tail," showing that the great ice-sheet passed over their very summits, high as some of them now are (Plate VIII., fig. XI.). In the middle part of the valley, and especially E. of the Garnock, the surface, where not broken by projecting outcrops of the harder rocks, presents long sweeping guttery and curved surfaces, like large ridges and furrows, and in the latter run the streams which drain the district. The ridges are so conspicuous as to have

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suggested names in the olden times to several districts, such as Lugtonridge, Swinridge, etc. That the movement of the ice had to do with the formation of both ridge and furrow I think there can be no reasonable doubt. They have been formed without respect to the dip of the strata from which they are carved, and in many instances the Boulder-clay is thicker *on the ridges* than in the furrows between them.

In the lower part of the Garnock Valley, from a short distance above sea-level up to about 200 feet, the country is singularly hummocky, and the hummocks or drums are so conspicuous at this level that at this part it might not inappropriately be called the "Drum Country." These drums are entirely of Boulder-clay, up to 40 or 50 feet in thickness, and seem to have been carved out of the longitudinal ridges already mentioned (Plate IX., fig. XIII.) when the land was subsiding below the sea-level, and modified no doubt when it was again rising.

[Since this paper was in type, the Seventh Annual Report of the U.S. Geological Survey has come to hand. Prof. Chamberlain, the author of the Memoir on Ice Scorings, gives it as his opinion that the Boulder-clay drums or drumlins were formed by the *second* ice-sheet, which carved them in a manner similar to that in which it acted when passing over syenite districts. This appears to me to be a very feasible explanation of the formation of drums, but in the case of our Ayrshire ones, there can be no doubt that the sea has been amongst, at least, the lower lying ones. Jan. 1891.]

As already mentioned, when the glacier and its Boulder-clay passed over soft rocks, such as shale, soft sandstone, and ash-beds, tearing up and crushing of the rock took place. Should harder rock be passed, the tear and wear on the soft and the hard rocks would be very unequal, the ultimate result being the formation of a rock-bound hollow as first suggested by Sir A. Ramsay, and when the ice melted away such hollows would become filled with water, forming a loch like Blae Loch, the basin of which has been scooped out of the ash-beds below the lower limestones. Indeed that part of the Garnock Valley between Kilbirnie and Kilkush is such a rock-bound hollow scooped out of the Lower Carboniferous shales and sandstones, the bottom of which at some parts is just about sea-level.

In the progress of such a mass of glacial ice as that under

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consideration one might expect to find that it had left a very thick accumulation of Boulder-clay—*a mixture of all the rocks over which it had passed.* But we have seen that this is not the case, and that it partakes more of the nature of the rock over which it had *immediately* passed. A ground-moraine glacier must therefore have some way of getting quit of a lot of its material as it moves along. It is well known that a glacier discharges, at its lower end, a large quantity of *muddy* water, which comes from the ice melted by the heat generated by the continual friction. This appears to me to have been the manner in which the great ground-moraines got quit of a large quantity of their accumulated material in the shape of fine *mud*, and which was possibly deposited on the ocean bed. At the lower end of the glacier, where the quantity of water was greatest, *all the mud* would be naturally washed away, and hence it is that at the end of modern glaciers there is not any *Till*, but only moraine matter, all the clay having been washed from amongst the stones.

The farther a stone travelled in the ground-moraine it would likely, according to its hardness, suffer the more. Hence the granites from Ben Cruachan and hornblendic felsites from Glenfalloch found in the Garnock Valley are all small blocks, while the softer red sandstones, which have not travelled half the distances, are reduced to mere pebbles. On the other hand, many of the local blocks, which have only been moved for a few yards, have their angles remarkably sharp.

We have seen at Lissens that blocks of sandstone were torn from the *end* of beds (Plate VI., fig. I.) merely by the friction on them of the ground-moraine aided by the pressure of the superincumbent ice. But the glacier had greater power when it came to push against a hill-face. As the ice began to gather and thicken, the loose blocks from the higher crumbling faces would be the first to get frozen into its mass. When a hill got entirely enveloped in the ice, mechanical force would come into play, shoving at first all the loose blocks from the shoulders and summit. As the ice increased in force and power, blocks more firmly fixed would be torn off and borne away. But we see from the rounded, striated, and smoothed tops of the present hills that there was a limit to this wholesale *quarrying*, and that the ice, aided by the rocks frozen into it, acted as a rasp or file, rubbing away such particles as it could detach from the compact rocky surface, and

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in this way we have those bald-headed hills with long grassy tails so common in the Kilbirnie and Dalry districts (Plate VIII., fig. XI.).

Where the action of the ice was not continued long enough to plane the brow of the hill down to a resting slope, or where perhaps there were more easily abraded rocks further down on the stoss side, we have left there steep hill-faces directed to the north (Plate VII., fig. VII.), where subsequent weathering has detached many angular shivers, which now form a long brecciated scree on the hill-slope so very different from a ground-moraine, although, like it, partly the product of ice.

As to the average thickness of the Boulder-clay in the Garnock Valley, it is of course impossible to form a correct estimate. We have seen that in some favoured spots it attains a thickness of 70 feet, and I think this may be taken as about the maximum. But taking the whole area, hill and valley, the average thickness will not probably exceed 10 feet. There is of course much more of it, area for area, in the lower part of the valley than amongst the hills.

There is an almost entire absence of moraines in the Garnock Valley, and I can only point to a very small lateral one 90, yards long by 30 yards broad, on the lands of Swinlees, and another near the head of the Lugton Water in the valley a short distance beyond Lochlibo. From the abundant evidence we have of such a mass of ice having for a long period passed over the district, it may at first seem a little startling that moraines are not both large and numerous, but when we reflect that the movement of the Garnock Valley ice owed its mechanical energy, not to any power within the valley itself, but to the outside pressure from the combined ice coming *up* the Clyde from the Highlands, and that coming *down* the Clyde Valley from the higher reaches of Lanarkshire, we shall see at once that so soon as the ice-sheet had sufficiently melted to allow of it *all going by the Firth of Clyde*, the ice in the Garnock Valley would simply be brought to a standstill, and, with a few local exceptions, just melt where it stood. I think that in this way we may explain the absence of moraines in the Garnock Valley.

During a recent extension of railway lyes at Kilwinning station a section of Boulder-clay was laid open which was seen to be contorted and curved in a most remarkable manner (Plate VII., fig. VIII.). After studying this curious section for some time, I came to the

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conclusion that the contortion could only have been brought about by an iceberg grounding, the ice having been pushed for some distance in amongst the beds of Boulder-clay, sand, and gravel, curving and twisting them in the most fantastic manner. The age of the sand and gravel beds could not be ascertained owing to the entire absence of fossils in them, but it is not improbable they are Post-tertiary, as we have no evidence of icebergs having frequented the seas in this quarter during the Raised Beach period.

We often hear geologists speaking of lake hollows and depressions as *pre-glacial* because they *contain* Boulder-clay, and it is answered of course that the hollows are older than the Boulder-clay they contain. I cannot admit of this style of argument, for the process of hollowing out such "depressions" and "basins" can only have terminated through the machine and tools by which they were formed—viz., ice and Till having ceased to act—so that they cannot properly be termed pre-glacial, but must be called synchrono-glacial, as having been formed at the same time as the Boulder-clay which they contain. In the gritty sandstone districts of Pencot and in some parts of the upper portion of the Caaf area, Boulder-clay is either absent or very thin.

It has often been remarked that Craigmaddie Moor, north of Glasgow, is singularly free from both Boulder-clay and even boulders; and geologists well know that in districts where hard gritty sandstones belonging to the millstone grit formation occur the surface deposits are conspicuous by their absence, which peculiarity has earned for this series of strata the very appropriate title of "moor rock." This fact of the absence of Boulder-clay in such districts has never been explained so far as I am aware. But I think it can be very easily accounted for. If we take a piece of rock—say a small fragment of limestone—and rub it on a slab of shale, we shall find that by rubbing even for a very long time little or no effect is produced on the limestone. But let us substitute for the shale a slab of gritty sandstone, and matters are very much changed. Even under the comparatively feeble pressure of the hand the limestone gets "smaller and beautifully less" till it ultimately is resolved into dust. Similarly the Boulder-clay, in passing over a shale district, will suffer very little abrasion *from the shale*, but in being forced under the pressure of ice over a coarse gritty sandstone, the boulders, even the very hardest of them, will soon be rubbed away and ground into mud, and for the same reason the

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ice itself will suffer much more from friction—that is to say, a greater quantity of it will be converted into water, so that the mud produced from the grinding down of the stones and boulders will have a greater chance of being carried away by the streams which are constantly running under glacier ice. Thus the thickness of Boulder-clay in any district will be very much influenced by the nature of the rock over which it is being driven, and in gritty sandstone districts it may be very thin or entirely absent.

The average depth of Boulder-clay for the whole Garnock Valley area is probably not now more than 10ft., but I think this gives a very poor idea of the work done by the ice in this district during the Great Ice Age. From the rounded contours of the hills, from the probably high Miocene volcanic cones of lava and loose ashes now quite obliterated, and the hollows dug into the softer shales, the total average thickness of rock material abraded from the surface area of the Garnock Valley was probably very many times the amount of the Boulder-clay deposit still left. We have seen how rapidly the Till changes its character in the different districts in which it is found, taking almost at once the character of the rock over which it has immediately passed, or on which it may be resting, proving how large an amount of material glacier action was capable of grinding up and getting rid of as mud. We have also seen in the Surge Burn district, where the rocks are very hard, the Till has very little clay mixed with the boulders and stones.

Wherever an opening is made or natural section occurs in the Boulder-clay it is seen that 4ft. to 6ft. of the upper part from the surface seems at first sight to be a different and subsequent formation to the under part. For a long time I considered it to be so, but on closer study it proved to be simply "part and parcel" of the *moraine de fond.* Its browner or rustier colour and more open texture than that of the lower portion appears to have been caused by the greater weathering it has been subjected to, water and air having penetrated into it and acted on its constituents so as to render it opener—in fact, a first step towards its reduction into soil. On the soils resulting from Boulder-clay the best oats in the world, for which Scotland has been, as may it long be famous, are grown.

We have seen that vein-quartz pebbles are more or less scattered over the Garnock Valley, as they are over large parts of the surface of Scotland. No doubt some of these, if carefully assayed, might

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be found to contain payable quantities of gold, and in this way, by tracing up the reefs from which they were originally derived, valuable discoveries of gold-bearing quartz might be made. An old quarryman informed me that where Boulder-clay is "creeshy" the sandstone rock below it is sure to be good; the reason being, I suppose, that the overlying "creeshy" clay is impervious to water, which, if allowed to pass down through the sandstone, would carry away its binding carbonates.

We have seen that at Lissens blocks of sandstone have been drawn from their positions and carried off in the Boulder-clay simply by the friction of the Till and ice grinding over the sandstone bed. Amongst the hills a few instances occur where blocks of porphyrite have been drawn down from the *tail end* of large *roches moutonnées* (Plate IX., fig. XII.), and are left lying at varying distances in the direction in which they were being carried off, the parent rock being angular and broken, and presenting no rounding or signs of glaciation except on the top.

Within 50ft. or so of the top of Misty Law there is an accumulation of rock shivers arranged as if they occupied the site of an old sea-beach. In fact, at first sight one would think the tide had but recently left them. The shivers are all of small size and extend for some little distance along the S.E. front of the hill. They are rather difficult to account for, and are lying far too flat to have formed part of a scree of rock débris. We know that in the Arctic regions the ice-foot breaking up during summer carries along and deposits angular rock-fragments in the form of regular beaches. A sheep farmer I met on the hills informed me that there were similar accumulations of shivers on several parts of the moors, and at much lower altitudes than those on Misty Law. This matter is certainly worth further investigation, as it may be the means of showing that the sea since glacial times stood at a much higher level in Scotland—as it is supposed by some geologists to have done in Wales—than we have elsewhere any proof of.*

Prof. J. Geikie thinks that, when the ice had melted from the lower reaches of Lanarkshire, the Lochlomond glacier, issuing into the Clyde at Dumbarton Rock, blocked up the passage, and the river accumulating in an inland loch near Glasgow, rose high

* Since this was in type it has occurred to me that these deposits of rock may have been carried down from the hills by snow.

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Fig. I.—Section, at Lessens, shewing how Sandstone blocks were friction-quarried. Arrow indicates direction of Ice movement.

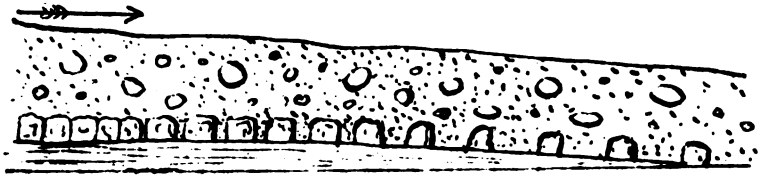


Fig. II.—Section near Kilbirnie, shewing Sandstone block, 5 ft. long by 20 inches, right on end in Boulder-clay.

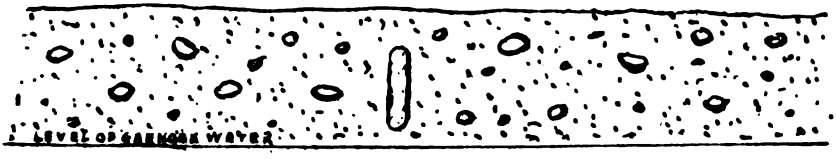


Fig. III.—Section of Boulder-Clay, Snaker's Quarry, 12 ft. high Sandstone with clay joints 2 to 3 ft. down, at S. Above it angular pieces of Sandstone not long taken up by Till. Till near rock is very sandy, and shows horizontal shear planes looking like lines of stratification.

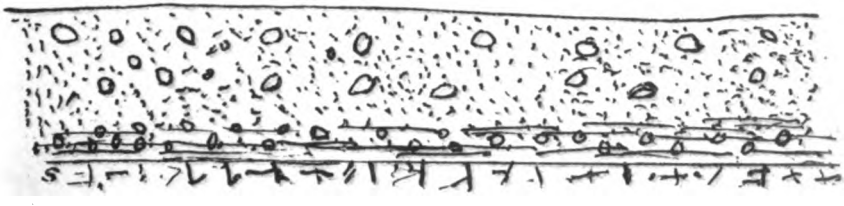
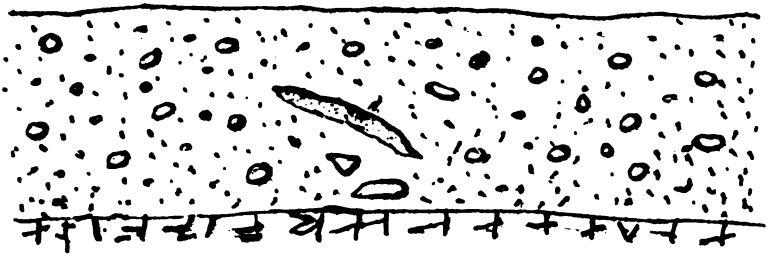


Fig. IV.—Section of Boulder-clay, Snaker's Quarry, with patch of pure sand 6 ins. at thickest part and 4 ft. long. Muddy sand in the pure sand at A.



JOHN SMITH, DELT. SECTIONS IN THE GARNOCK VALLEY. CARTER & PRATT, LITHOG.

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Fig. V.—Section, at Lissens, shewing crushed-up mass of black shale with Boulder-clay under it resting on crushed black Carboniferous shale.

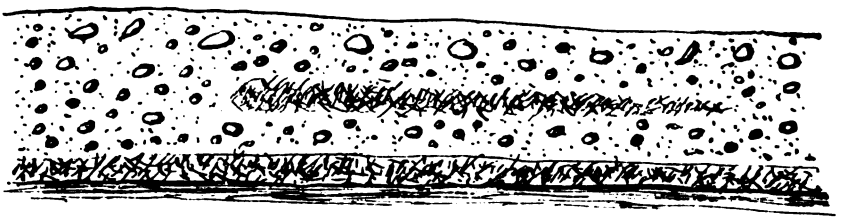

Fig. VI.—Section of Smithstone Dolerite Quarry shewing Boulder-clay occupying a hollow where the rock is soft. No Boulder-clay on top of hard rock.

Fig. VII.—View of Glenfon (790 ft.) and Gill Hills, shewing "Crag and Tail."

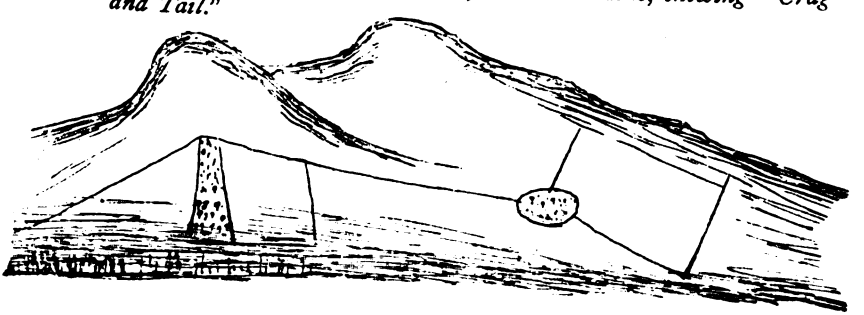

Fig. VIII.—Part of a section (6 ft. high) near Kilwinning station shewing, at B, Boulder-clay (Ground Moraine) crushed up amongst contorted sand and gravel beds, A.

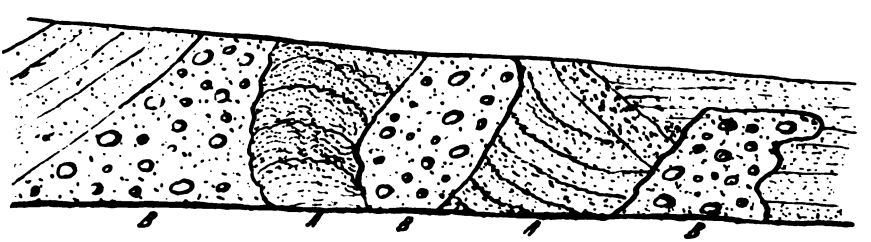

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Fig. IX.—Section near Smithstone House, 22 ft. high, shewing Iceberg, Boulder-clay, stratified sand, and Ground Moraine.

Fig. X.—View of the Volcanic Necks, in Carboniferous strata at Castle Hill, near Kilwinning, shewing "Crag and Tail."

Fig. XI.—View of top of Misty Law, 1663 ft. high, shewing "Crag and Tail."

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Fig. XII.—View of Lamb Hill, Ladyland Muir, shewing "Crag and Tail," and how rock at Tail end has been friction-quarried and the blocks of stone mostly carried away. Tail ends called "The Rotten-craigs."

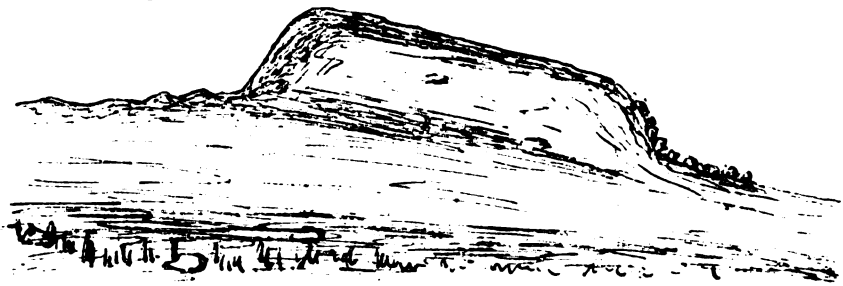


Fig XIII.—View of part of Drum Country near Flemland, shewing how longitudinal ridges of Boulder-clay become broken up into Drums. Arrow indicates direction of Ice movement.

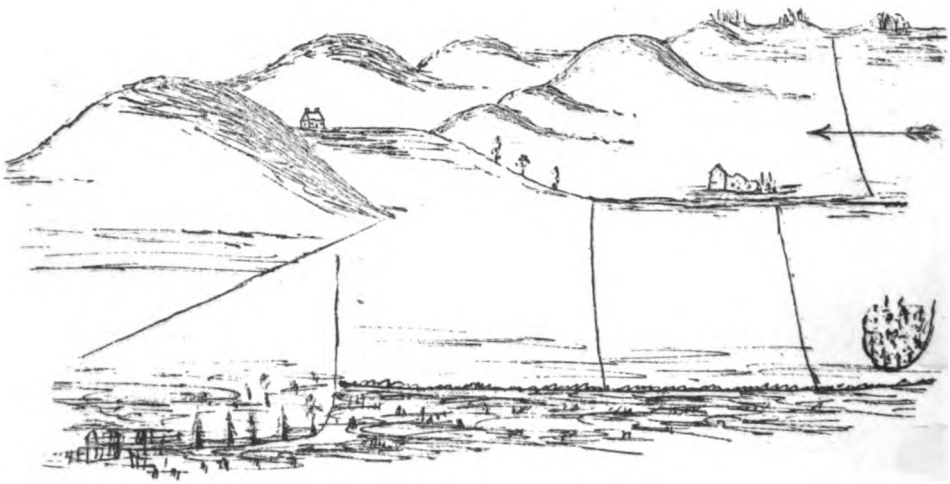
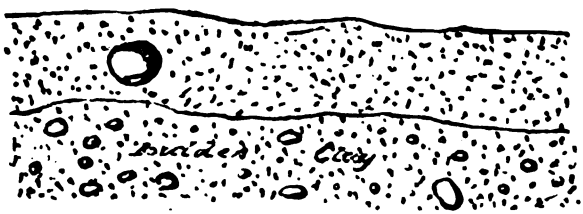


Fig. XIV.—Section at side of Sourlie Ry. shewing boulder 3 ft. diam. embedded in gravel, 90 feet above sea level.



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enough to be able to flow *viâ* Lochwinnoch and Kilwinning to the sea, so that what we now call the Garnock Valley was then the lower portion of Clydesdale. I see nothing to hinder this to have been the case, and it was probably during this time that the deep hollow from Dalry extending away in the direction of Paisley was partly filled with sandy clay and mud—Lochwinnoch and Kilbirnie lochs being the only parts not yet entirely filled up, the former of which will very soon be, but the latter will remain a loch for a long time yet. It was probably also the Clyde that cut the passage through the thick Boulder-clay at Monkcastle, where so many boulders are now seen in the bed of the Garnock. Had this not been accomplished when the Lochlomond glacier blocked up the Clyde at Dumbarton, the Caaf, having for tributaries the Rye, Garnock, Maiche, Calder, Gryfe, and White Cart, would have flowed into the Clyde at Renfrew. We have already seen that wherever the rocks are of a soft nature they have suffered to a much greater extent than where they are harder. We see this in a very marked manner at Smithston dolerite quarry, where a hollow has been worn in a soft part of the rock and contains Boulder-clay, whilst there is none where the rock is hard (Plate VII., fig. VI.).

In conclusion I have to express my thanks to Messrs. Peach and Bennie of H.M. Geological Survey for information about some of the boulders noted in this paper.

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No. XI.—Notes on Gairloch, Ross-shire. By James White, *Hon. Librarian.*

[Read 11th October, 1888.]

Gairloch is the name of a parish and of an arm of the sea in the west of Ross-shire. The parish is a large one, being about 30 miles long by 20 broad; the arm of the sea is 4 miles long by 2 broad at its entrance, and is distant from Oban about 140 miles, or eleven hours' sail. The sail from Oban to Gairloch is a popular one with the tourist, the sight-seer, the health-seeker, the archæologist, and the student of physical geology, as it presents features which call up associations of surpassing interest. It is, however, with its geological aspects that we are at present concerned.

Few geologists are unacquainted with M'Culloch's volumes descriptive of the Western Islands of Scotland, and few of them fail to appreciate the great amount of labour and care necessary for their production. Whatever imperfections they may have when viewed in the light of the present day, they are a wonderful monument of industry and painstaking for a pioneer geologist.

Then these are the waters traversed by the "Betsy;" and if the Free Kirk never did any other service to the cause of geology, it deserves to be thanked for this, that it afforded Hugh Miller an opportunity of exploring regions and localities which otherwise would have been to him impracticable, and so enabled him to write some very fascinating books, which showed an enormous advance upon the then existing state of knowledge upon their various subjects.

Coming down to more recent years, Prof. J. W. Judd has read the geology and specially the petrology of these western regions with a fulness and a clearness hitherto unattained. His papers on the Secondary and on the Volcanic rocks of Scotland bulk largely in several volumes of the *Quarterly Journal of the Geological Society*, and may be said to mark a new departure in the study of the science. That on the volcanic rocks (*Q. J.*, vol. xxx.) is of special interest. The author has traced, especially in Mull, the passage of one kind of volcanic rock into another all through the various stages from tachylite to gabbro. He has shown that they have a connection, a common origin, a common descent, which it is neither fanciful nor unscientific to describe as a vital one, and so has added another and what seems to be almost the crowning

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triumph to the doctrine of uniformity so closely associated with the name of Lyell. For this is really the principle which underlies and gives stability to all scientific progress. Interpret the past by the present, take your cue from nature itself, reason from what is going on around you to what has always gone on, from what is known to what is more obscure.

Then we have recently had from the pen of Dr. Archibald Geikie an apparently exhaustive sketch of the sequence of events comprised in the history of these Tertiary volcanic rocks. One quite wonders at its comprehensiveness and its mastery of detail, and how, from materials which are so very fragmentary, so complete a narrative could be constructed.

With such recollections in his mind as he is piloted through amongst these old volcanic stumps—Mull, Ardnamurchan, Rum, Skye—your geological pilgrim has something akin to those feelings of reverence which a Mahommedan may be supposed to have as he enters Mecca and sees before him in very truth those objects whose story has been told him so often and so vividly. Or like those of a Christian as he enters some venerable cathedral and gazes on its lofty proportions, its richly-stained windows and its magnificent paraphernalia of altar service seen through a "dim religious light," and thinks of what all this is intended to conserve.

Gairloch is cut out of the rocks described by Murchison as "fundamental gneiss." This term, however, must be understood as generally applicable to the whole formation of which those rocks form a part. At Gairloch they are not gneiss, but schists, with occasional beds of hardened sandstone, and are far less metamorphosed than those rocks with which we are so familiar on the northern shores of the Clyde.

The Torridon sandstones, which occur in low-lying masses on the north side of the loch, and appear in great force on the south, form a magnificent background to the bare dome-shaped masses of the gneiss, and overlie it with the most marked unconformability. Those quartzites, which, unconformably, cap the sandstones, form in places the basement beds of a comformable series, some of which are fossiliferous—the uppermost, the limestones, having yielded fossils of a distinctly Silurian character. These fossils have determined the age and relations of the rocks in this neighbourhood. The uppermost conformable series is described as "Silurian," the underlying unconformable Torridon sandstones as "Cambrian,"

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and the still more unconformable gneiss as "fundamental," the local names being "Hebridean" or "Lewisean," or "Laurentian," to name them in accordance with the usual geological scale, the physical breaks being recognised as forming these several divisions. By most writers these lowest "fundamental" rocks are described as "Archæan," and are excluded from the palæozoic series.

This, I presume, is in strict accordance with the present state of knowledge, as nothing to undoubtedly indicate the presence of life has hitherto been seen in them. It is obvious, however, that this is quite a provisional arrangement, there being many horizons which yield no fossils, but which overlie, and are therefore of later date than, strata which are fossiliferous, so that the absence of organic remains is not of itself sufficient evidence of their age, or to show that they have never contained any fossils; as these would in all probability be few in number, simple in character, and may very readily have been obliterated by the great changes through which those rocks have passed. At the same time it seems highly probable that sedimentation may have been carried on at a date long anterior to the appearance of living things, and under conditions in which life, as known to us, would have been impossible.

The organic world is supported from the inorganic, the plant and the animal from the mineral, but neither plants nor animals can live on stone, hard rock, or solid mineral by itself, their food being taken in a gaseous or fluid condition, and requiring to be prepared for them; so that the rocks of the first formed, the first condensed crust, must have been highly pulverised and finely divided before life could find a footing, and this could only be done by the agency of water.

Speaking generally, plants live on minerals, animals live on plants. When pushed to its lowest limit, however, the distinction between these two great kingdoms disappears, and the most arbitrary characters have to be selected to define the one from the other. The outstanding rule seems to be that the simple precedes the complex, the less precedes the more highly differentiated; and accordingly we find that what evidence there is for the existence of life in those Archæan rocks is referable to the plant rather than to the animal. An animal is more highly organized than a plant, has a greater number and a greater variety of parts, is better furnished with the means of offence and defence, and, according to this theory, would appear later in time.

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Although no clearly recognisable well-defined fossils have been seen in these Archæan rocks it by no means follows that they were destitute of life. The *Lingula*, though it has persisted down to the present day, doubtless had an ancestor which was not a *Lingula*, and the *Oldhamia radiata* sprang from something which preceded it, and so with the other and more highly differentiated forms which Cambrian rocks bring to view.

The boundary of the palæozoic system is wholly unknown. Advantage is taken in this case of a well-marked physical break as a dividing line, but it is entirely arbitrary, and may at any time be thrown indefinitely backwards.

But this whole subject, which is replete with interest, is very fully discussed by Prof. Dana in his "Text-Book."

At Gairloch these rocks vary very much in their character—some are quite hard and splintery, others are softer and not far removed from an indurated shale. Beds of sandstone also occur here and there; evidently they are mechanically-formed shore deposits, and have at one time been a series of sandstones and shales such as we are familiar with among rocks of later age round Glasgow. The plane of schistosity coincides with the plane of bedding, the dip is vertical, and no means are here available for estimating their thickness. It seems, however, that further north they are thrown into a series of synclinal and anticlinal folds, from which they have been estimated to be at least 20,000 feet thick; but nowhere is the base visible. There is another feature of these rocks of unusual interest—the extremely rounded bossy forms into which they weather. Many other rocks, especially schists, take this form, but these have received it and retain it in an unusual degree. As you sail into Gairloch and gaze on their dome-like bleached and barren masses in the full glow of the afternoon sun you are at once struck with this peculiarity; nothing like it has occurred all the way, though you think you have exhausted every form of rock contour of which nature is capable. They have an almost ghastly look, innumerable knolls of a bare, dull, verdureless, ashen grey. These rocks are overlain by the sandstones, and, singular to say, in places where the junction of the two can be traced, the rounded bossy form of the gneiss is seen to persist under the sandstone. Clearly it had acquired it before the sandstone was laid down.

This rounded bossy form is by all geologists attributed to the

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action of land ice. Wherever it is found, even in tropical countries which are now even farther out of the reach of such action than our own land, it is accepted as proof that "John Frost" has been there, for there is no other known agency which can produce such features. Elevation from beneath is out of the question, as these Gairloch schists stand on end; and for the same reason a puckering up of the crust by lateral pressure is out of the question. Atmospheric weathering gives us stacks and needles and other splintery forms, but a heavy mass of moving ice coming on a country which has been previously subjected to atmospheric weathering planes off the asperities which are thereby produced, and leaves instead bossy rounded forms, which may be either great or small according to the condition and character of the land at the time of its advance.

The plain inference from all this is that we have in these Gairloch schists an example of glacial action in early Cambrian times.

Dr. Archibald Geikie was the first to notice this, and to call attention to it in a paper (*Nature*, Aug. 26, 1880) which he illustrated by some drawings and a diagram of two sections; the latter I have

a *b*

here reproduced. The first (*a*) occurs a little way up the hill immediately behind the Gairloch hotel, and the second (*b*) on the shore immediately to the south of the Free Church.

The Duke of Argyll in a communication to a subsequent number of *Nature* challenged the accuracy of the drawings.

Not having seen the localities of the drawings I don't discuss them, but having gone over the originals of the sections several times I can testify that they are not at all exaggerated; in fact if I had drawn them myself I would have shown the rocks as much more rounded than they are represented. I think most of you will be of opinion that these contours are not such as splintery schistose rocks standing on end would acquire from ordinary atmospheric weathering.

There are other features in the neighbourhood which point in the same direction, as, for example, the extremely rough angular character of the breccia which lies immediately on the schists.

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Many blocks in it are from 3 ft. to 6 ft. long, all derived from the underlying rocks, and as sharp and angular as if they had been split off yesterday. Clearly such a mass of material was never brought together by the agency of water; it is vastly more like moraine matter which has not travelled very far.

Prof. Sir Andrew Ramsay, in his address to the British Association Meeting at Swansea, of which he was president, quotes this section of Dr. Geikie's in illustration of the subject of his address, "On the Recurrence of Certain Phenomena in Geological Time." Amongst other recurrences he finds what is to him satisfactory evidences of that of glacial phenomena, and writes:—"The general subject of palæozoic glaciers has long been familiar to me, and this account of more ancient glaciers of Cambrian age is peculiarly acceptable."

Poolewe is worth a visit were it only to see the débris of what must have been a very massive glacier, which, there is so much evidence to show, at one time swept down to the sea through the valley now designated Glen Docharty, Loch Maree, and Loch Ewe. This débris is of the most imposing character; you have boulders on the hilltops cutting the horizon in the most fantastic manner, and boulders strewn along the hillside, boulders single, boulders in groups, boulders angular, boulders rounded, boulders of sandstone, and boulders of gneiss. It seems reasonable to conclude that all this matter is the product of the latest glaciation of this valley, as these boulders appear to be local. I went up the hillside about 400 feet, and all that I saw were schists or sandstones. If those on the tops of the hills are also local, then they probably belong to the same period of glaciation, and in this case the ice must have quite filled the valley and have been sufficiently high above it to strand stones on the ridges. It would then be better described as a *mer de glace* than as local glaciers.

The stones at the bottom of the valley are all smaller and more rounded. Clearly they have suffered more attrition than those on the hillside, and have formed a moraine which has stretched across and filled the whole valley. A retiring glacier turns into a river, and these stones, as they have been acted upon by water more recently than by ice, are now just a mass of very coarse gravel. From a change of level the River Ewe now cuts through this moraine, and the sea, entering from Loch Ewe, cuts into it, so that we have along the banks of the river and at the head of the

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loch a very well-marked terrace, which might be described as a Raised Beach. Nothing could be plainer or more evident, and it is worth going all the way to see. We have here the closing stages of the Ice Age clearly indicated in a rising land, retreating glaciers, and an ameliorating climate.

But all this work is of an entirely local character, limited in time, limited in space, and, although we had read twenty such localities, or all the superficial features of the county put together, we have not read the history of the Ice Age. It cannot be seen in the superficial features of the country; you must dig for it, as it is from the digging that the revelations come. What about those six distinct and separate Boulder-clays which some deep bores pass through (see *Transactions*, vol. iii., p. 133), each separation being indicative of a period when the formation and deposition of the clay was suspended and its place taken by sand or gravel or mud, materials which are in no way connected with a cold climate, and which could not by any possibility be brought together under the same climatic conditions as Boulder-clay; and these not occuring in small lenticular patches, which prove nothing either one way or another, but in wide spreading beds 60 ft. to 100 ft. thick?

We must take the maximum number of these indicated changes as the minimum number which has occurred, and so the question is at once raised, how often has this valley of the Ewe and how often have similar valleys been blocked up with this débris and then wholly or partially cleared out? Are we, after all, sure that all the material we see is the product of the *latest* glaciation? According to theory, 20,000 years would be the interval between each period of intense cold, but this is short. According to theory, 80,000 years have passed away since the last period. All the big stones you see are local schists and sandstones, the rocks which lie in the line of the passage of this glacier; but how many glaciers have passed down this glen, and have the lines of drainage which pass into it always been the same? Physiographers point out to us very clearly changes which have taken place in some of the water-sheds of the country, and ice-sheds obey the same laws as water-sheds. Is it a far-fetched, ill-informed thought that there may be stones amongst those hundreds which you see strewn along those hillsides, or those millions which cover the bottom of that valley, which, as to their derivation, may be widely separated

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from each other both in time and locality? There are many districts which could furnish schists and sandstones; the same kinds of rocks have been forming ever since time began. The late Mr. Pratt, a well-known member of this Society, spent a large portion of his leisure time in sectioning crystalline rocks, and all his acquaintances had commissions to pick up for him specimens of them wherever they might come across them, the result being that he came in time to possess a large number of sections—over 300. As the sources of supply from rocks *in situ* became exhausted he collected specimens from the Boulder-clay and sectioned them, thus gathering another series of sections, a great many of which were of quite a different character from his first collection. These he could not possibly identify with the rocks found *in situ*, although he was in every case careful to note the locality where the parent boulders had been found.

In Dr. Croll's book on "Climate and Time" a chart is given showing the probable centres of dispersion of ice during the period of maximum glaciation, and one of these centres is in the North Highlands, where the land rises to between 3000 ft. and 4000 ft. The subsequent detailed mapping of that district by the officers of the Geological Survey has unexpectedly brought to light the fact that this was a mistake. So, as these centres of dispersion all balance and are all related to each other, if one has to be changed so must the others, leading probably to an entire reconstruction of the chart in question, and to still wider conceptions of the extent and thickness of the icy covering.

Then as to submergence. It is Dr. Croll's, and I think the general belief, that the change in the relative levels of sea and land was brought about rather by an advance of the sea, due to the displacement of the earth's centre of gravity by the great mass of ice at the pole, than to an actual sinking of the land, or at least that this was a powerful factor. Should this be correct, then, if we are to have a greater weight from a greater thickness of ice than was at one time supposed, so we must also have a greater submergence than was at one time supposed.

Such are some of the thoughts which in my own way I have had the temerity to ventilate in view of some discussions which have recently taken place in this Society and elsewhere. It seems to me that, in these matters, as generally in nature, it is impossible to draw hard and fast lines; that there is room enough for all;

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that geologists cabin, crib, and confine themselves by taking too limited a view of such operations; and that if these are looked at in their true proportions much difficulty might disappear. Within its real compass we may quite well have boulders, many stranded by retreating ice, and we may also have boulders, many of which as certainly have been dropped from passing icebergs. In some cases the difference is quite easily defined, in others it is by no means evident. May they not sometimes lie side by side?

When we have a past president of the Geological Society telling us that the ice-cap in Scotland was 3000 ft., and in some places 5000 ft. thick; and another past president telling us, just the other day, that there never was an ice-cap in the country at all; when we have geologists who contend that there is no evidence whatever to show that the land was ever sufficiently submerged to allow icebergs to float over it and drop erratics on its surface; and other geologists who contend that all the glaciation which it has undergone has been due to floating and not to land ice at all, it is surely apparent that there is a vast deal of speculation going on, and that more careful and cautious and accurate observation than has hitherto been bestowed on these questions is called for.

So much for another glimpse of "our stern Scottish Highlands," a land famous in song and story, and a land of perennial and ever-increasing interest to all dabblers in physical geology.

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No. XII.—Note on the Occurrence of Footprints in the Calciferous Sandstone between West Kilbride and Fairlie. With a Drawing to Scale. By John Smith, Kilwinning.

[Read 14th November, 1889.]

On 12th June of this year, whilst examining the fine section of red Calciferous sandstone which is exposed in the cutting of the Ardrossan and Largs Railway, situated about two and a quarter miles north of West Kilbride, I was not a little surprised to discover a double row of what appeared to be the fossil footprints of some animal. When the cutting is entered from the south end a white post, with "¼" painted in black figures on it, will be seen. The footprints are on the east side of the cutting, opposite the 102nd sleeper from the post mentioned. In other parts of the cutting there are also a few prints, but these are the best marked.

The sandstone at this point dips towards the east at the high angle of 80°, and the footprints are seen *in relief* on the under surface of the stratum of rock. The prints are in two rows, the right hand one showing six and the left hand one seven impressions, and they run in a S.W. and N.E. direction. No doubt if the rock was further quarried they would be found to continue for some distance more or less. The prints are all much of a size—about three inches long by two broad and half an inch deep. The spacings, measured from centre to centre of the prints, are, for the right hand row, 8, 8, 8, 7¼, and 8½ inches, and for the left hand row, 8, 8, 8, 8, 6½, and 8 inches respectively, and the lateral distances apart are from 6 to 6½ inches from centre to centre. They are, of course, all pretty much abraded, having been exposed to the weather since the cutting was made some years ago, but are still very distinct, though the finer features are gone. They are roughly oval in outline, and some of them show a slight notch on what was probably the fore part of the foot, which in both rows inclines slightly inwards.

Mentioning the matter to Messrs. John Young, James Thomson, and other members of the Society, I found none of them had heard of footprints having been found so far down as the Calciferous sandstone. I also wrote our member, Mr. James Bennie of the Geological Survey, who from his position was likely to know the

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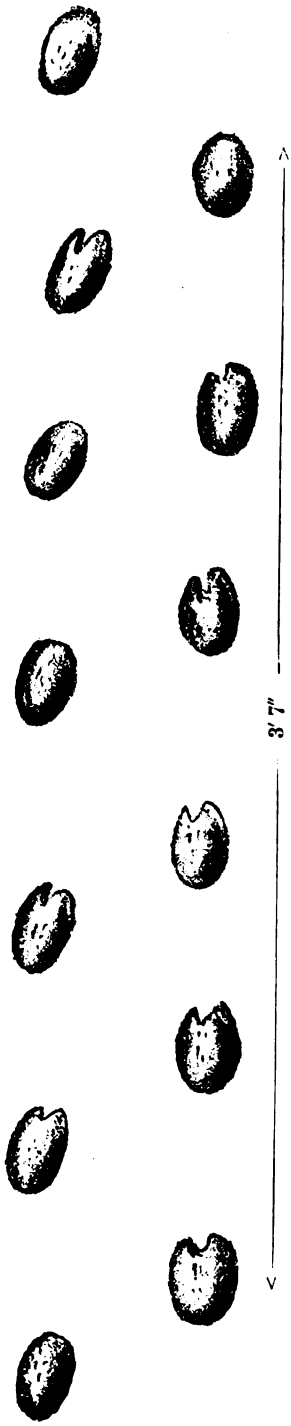

"latest" in regard to such matters, and he, in his characteristic style, wrote at once—"In reply about footprints in the Calciferous sandstone, I don't mind of any, and if yours are four-footed you should ring the bells loudly at once, as we want much to get beasts with feet other than scorpions in that part of the formation."

Dr. Buckland, in his "Geology and Mineralogy," plate 26, figures some footprints from the New Red Sandstone of Corncockle Muir, near Dumfries, which he describes as "fossil footprints indicating the tracks of ancient animals, probably tortoises." They agree pretty much with the ones under consideration as regards size and lateral distance apart, but the "pacing" is altogether different.

Hugh Miller, in his "Fossiliferous Deposits of Scotland," printed at the end of his "Old Red Sandstone," page 367, says that the "footprints of a much larger reptile" (than *Parabatrachus colei*, Owen) have been "detected in our Dalkeith coal-field by Mr. Henry Cadell, the experienced and intelligent mineral surveyor to His Grace the Duke of Buccleuch."

At the meeting of the British Association of this year, held at Newcastle, Mr. T. P. Barkas read some "Notes on numerous newly-discovered Fossil Footprints on the Lower Carboniferous Sandstones of Northumberland, near Otterburn."

Much discussion has taken place as to the age of the Elgin sandstone, in which both footprints and remains of reptiles have for a long time been known, but as to whether the "balance of evidence" points to these rocks belonging to "Old Red" or "New Red," or to some other formation, I am not prepared to say.

The section in the railway cutting between West Kilbride and Fairlie, apart from the footprints, is well worthy of a

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visit from the members of the Society. Nowhere could I point to a finer display of ripple marks, sun cracks, worm tracks, and rain pittings than are there to be seen. As the sandstone dips at the high angle of 80°, the railway at this part may be said to be bounded by inscribed walls. The sun cracks are magnificent, some I measured being eight inches long by five broad, and one, to one and a quarter inches deep. They were filled with soft red shaly sandstone. The ripple marks are of a great variety of sizes, ranging from three-quarters of an inch to three inches from ridge to ridge, and very distinct and sharp in outline, running in the different beds in almost every direction. Some have their ridges neatly shaved off, as if the beds had been moved in the deposition plane, probably during the time when they were being tilted to the high angle at which they now rest.

No. XIII.—Notes on the Excursion to the New Reservoir for Bowling Water Supply on 23rd March, 1889. With a Drawing. By W. J. Millar, C.E.

[Read 11th April, 1889.]

The Secretary having asked me to give a short description of the special features noted during the excursion, I may say that little need be said in regard to the Bowling district in general, as the members of this Society, from frequent visits to the well-known quarry, so rich in minerals, near the village, and to the glens in the neighbourhood, are quite conversant with the geological aspects.

The main object of the special excursion was to examine some well-marked glaciated rocks exposed during the excavation of the new reservoir just completed for the Bowling water supply, a few notes in connection with which may be of interest, and may serve to elicit information from members who were present or who may have made this interesting department of geological research their special study.

The site of the reservoir is at an elevation of about 600 feet above sea-level and about three-quarters of a mile to the north of the village of Bowling. A branch of the Auchentorlie Burn running through a hollow constitutes the feeder to the reservoir.

On the south-east side there is a rocky crest of trap very much weathered and broken up.

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RESERVOIR FOR BOWLING WATER SUPPLY—LOOKING EAST.

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The ground to the north, north-east, and north-west is open moorland.

On proceeding with the excavation it was found that an abundance of clay could be got, and, throughout the whole work, even at depths from the surface reaching to fully 15 feet, nothing but clay was met with.

On removing the soil and excavating the clay on the south-east or rocky side, it was found that the rock changed from the irregular fissured and friable condition where it had been exposed, to a close, compact whin of a bluish shade, and gradually, as the clay was removed and the excavation proceeded, great bosses of finely-smoothed rock were exposed, with striæ running across the surface. It is needless to say that the rock *in situ* around Bowling is trap, or whin, as it is commonly called, several interesting varieties being found in the district.

In the clay itself great quantities of boulders were found—rounded, smoothed, and striated. These were afterwards broken up and used for the pitching on the water face of the embankment.

Had the weather on the day of the excursion been fine the members would have fully enjoyed a walk over this pitched surface, as it constitutes quite a geological museum of rock specimens.

As it was, those present, who from great experience were most capable of judging, were much pleased with what they saw, not only in the case of the finely-smoothed rock surfaces *in situ*, but with the varieties of rock which had been carried from a distance and deposited as boulders.

The glaciated surfaces face north-west and north, and from compass observations the action appears to have been from north-west to south-east.

The following are some of the varieties of rocks found as boulders in the clay. Doubtless some of those who were present will add others:—

Red or purplish sandstone.
Mottled sandstone.
Ironshot sandstone.
Quartzite.
Greywacke.
Mica schist. (Some specimens with pretty large flakes.)
Chlorite schist.
Porphyrite.
Amygdaloidal trap.
Dolerite.
Limestone.
Granite.

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Since the date of the excursion I have noticed in the pitching a fine section of what appears to be hard sandstone with stems of plants. I am not aware if any of the members noticed it. I had no means at the time of detaching a specimen from it, but will endeavour to do so before the water (now rising in the reservoir) gets to it.

The clay throughout was stiff and of a reddish hue. Some bands of an orange colour were noticed.

Some of the members noticed traces of manganese in the rock *in situ.*

The upper portions of the rock indicated more of a tufa character, whilst the glaciated parts were close and compact. These latter parts were wholly covered by clay and soil, and are now, doubtless, for the first time laid bare since they were smoothed by the ice-sheet. The surfaces extend to about 14 feet in depth of slope, the inclination being something like that shown in the sketch on p. 204.

Doubtless much clay and many boulders still remain in the bottom of the reservoir, as no rock was met with.

Excavation for about 15 feet in depth was made through the clay and continued downwards for several feet more in the line of the puddle wall.

The party returned by way of Auchentorlie Glen, permission being kindly granted by the proprietor, Captain Buchanan of Auchentorlie, and inspections were made of the coal-beds situated near the foot of the glen.

[For an account of these coal-beds lying under the traps of the Bowling hills, see *Transactions,* vol. ii., p. 149].

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No. XIV.—Journal of a Bore put down for Water at Thornliebank, Renfrewshire. With Notes on the Strata, by J. B. Murdoch, *Hon. Secretary.*

[Read 12th December, 1889.]

[Abstract.]

Mr. Murdoch said that the bore on which he now wished to make some remarks had recently been put down for water at the works of the Thornliebank Printing Company, Limited, Thornliebank, Renfrewshire, to a depth of 611 feet 6 inches. Through the usual alternation of blaes and fakes, thin beds of sandstone, limestone, and fireclay, the workmen struck first, at a depth of about 200 feet, a post of limestone nearly 7 feet thick, which he believed to be the Arden cement limestone, and, immediately below, a 17-feet bed of white sandstone. Then at 238 feet a heavy mass of sandstone in several posts was reached, its total thickness being above 50 feet, and probably representing the Giffnock sandstones. At a depth of 476 feet another bed of limestone, 7 feet 6 inches thick, was passed, probably the equivalent of the Cowglen, or Index limestone. No further strata of importance were afterwards met with, the coal seams passed through never reaching a thickness of more than a few inches. The object of the bore was not attained, no supply of water of any consequence having been met with, and the work was stopped at the depth above noted. Mr. Murdoch stated that as this bore was, so far as he could ascertain, the first which had been put down in this neighbourhood, he thought it was worthy of mention to the Society and of record in the *Transactions* for future reference.

At the close of the paper Mr. John Young, F.G.S., suggested that the failure to obtain a supply of water probably arose from the fact that the bore was put down near a fault which prevented the flow of water along the line of the strata. It might be found on further trial that a bore put down on the other side of the fault, if one really existed, would have a very different result.

Journal of Bore.

	Ft.	In.		Ft.	In.
Surface, Clay, and Stones,	5	11	Brought forward,	37	4
Dark Blaes,	8	4	Limestone,	1	1
Dark Fakes,	4	1	Dark Blaes,	33	5
Dark Blaes,	19	0	Limestone,	1	4
Carry forward,	37	4	Carry forward,	73	2

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	Ft.	In.
Brought forward,	73	2
Grey Fakes,	3	5
Limestone,	1	0
Fakes and Hard Ribs,	4	2
Limestone (Sandy),	2	4
Dark Fakes,	0	6
White Sandstone,	7	0
Fireclay (Fakey),	1	0
White Sandstone,	3	2
Parting,	0	3
Grey Sandstone,	4	3
Parting,	0	6
Grey Sandstone,	3	3
Fakey Fireclay,	5	2
Dark Sandstone,	6	3
Fakey Sandstone,	4	0
Sandstone, hard,	1	6
Sandstone,	2	6
Parting,	0	5
Sandstone,	2	4
Do., hard,	4	8
Do., softer,	4	7
Grey Fakes,	4	9
Dark Fakes and Ribs,	9	9
Dark Fakes,	9	3
Dark Fakes and Ribs,	3	3
Fireclay, coaly,	1	2
Dark Fakes,	1	5
Kingle Stone or extra hard Sandstone,	0	5
Fakes and Sandstone Ribs,	2	8
Dark Blaes,	0	10
Fakes,	0	6
Sandstone,	0	9
Do.. extra hard,	0	9
Fakes,	1	4
Sandstone, extra hard,	0	10
Fakes and Ribs,	7	8
Fakes,	3	0
Fakes and Ribs,	7	0
Sandstone,	1	0
Fakes,	0	9
Sandstone,	0	10
Dark Fakes,	7	0
Limestone,	2	7
Limey Fakes,	1	2
Limestone,	3	1
Fireclay,	0	11
Light Fakes,	5	3
White Sandstone,	17	1
Coaly Blaes,	0	5
Fireclay,	4	3
Fakes,	2	6
Sandstone,	0	8
Fireclay,	0	10
Do., Coaly,	1	4
White Sandstone,	49	3
Carry forward,	289	8

	Ft.	In.
Brought forward,	289	8
White Sandstone, extra hard,	3	9
Do., softer,	5	0
Fakes,	1	8
White Sandstone,	4	0
Do., extra hard,	1	6
Do., hard,.	4	0
Do., softer,	10	1
Fakes,	1	3
Sandstone,	37	5
Fakes,	0	9
Sandstone, hard,	1	0
Do., extra hard,	2	5
Do., softer,	2	2
Fakes and Ribs,	3	4
Fakey Blaes,	1	6
Sandstone,	0	6
Coal,	0	6
Sandstone, hard,	1	5
Sandstone Plies,	1	3
Sandstone, extra hard,	1	9
Fakes,	0	2
Fakes and Blaes,	5	6
Sandstone, hard,	7	5
Do., extra hard,	2	10
Do., hard,	2	11
Do., extra hard,	0	3
Do., hard,	0	7
Do., extra hard,	0	3
Do., hard,	0	6
Do., extra hard,	0	4
Fakes,	4	4
Sandstone, extra hard,	1	2
Fakes,	0	4
Sandstone, extra hard,	2	6
Do., hard,	1	8
Do., extra hard,	6	10
Do., softer,	0	8
Fakes,	1	9
Sandstone, hard,	1	2
Do., extra hard,	2	2
Do., hard,	2	7
Do., extra hard,	1	2
Do., hard,	1	0
Fakes,	0	4
Sandstone,	0	6
Fakes,	1	0
Sandstone,	1	4
Do., extra hard,	14	4
Do., softer,	4	6
Do., extra hard,	0	11
Do., hard,	2	4
Dark Fakes and Sandstone Ribs,	9	9
Dark Fakes,	19	11
Limestone (Arden),	7	4
Blaes,	1	0
Carry forward,	486	3

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	Ft.	In.
Brought forward,	486	3
Sandstone,	1	5
Do., extra hard,	1	7
Do., softer,	0	10
Do., extra hard,	1	11
Fakes,	1	4
Sandstone, hard,	0	8
Fakes,	0	10
Sandstone, hard,	0	5
Fakes,	4	7
Fakey Sandstone,	3	11
Sandstone, hard,	0	6
Do., softer,	1	6
Do., extra hard,	1	3
Fakes,	2	5
Light Fireclay,	0	5
Dark Fakey Blaes,	1	8
Sandstone, hard,	5	8
Fakes,	3	7
Fakes and Blaes,	2	3
Hard Limey Rib,	0	8
Fakes and Blaes,	0	2
Sandstone,	0	10
Parting,	0	4
Sandstone,	0	8
Parting,	0	3
Sandstone,	2	2
Do., hard,	4	1
Do., extra hard,	1	1
Do., hard,	6	4
Carry forward,	539	7

	Ft.	In.
Brought forward,	539	7
Dark Fakes,	6	9
Sandstone, hard,	1	10
Do., extra hard,	1	8
Do., hard,	2	7
Coal,	0	5
Fakes,	0	3
Sandstone, hard,	4	10
Do., extra hard,	4	7
Fakes and Ribs,	2	11
Fakes, dark,	7	0
Sandstone, extra hard,	1	10
Dark Fakes,	1	9
Sandstone, hard,	1	3
Dark Fakes,	2	0
Sandstone, hard,	3	3
Do., extra hard,	2	9
Do., hard,	1	7
Sandstone, extra hard,	3	6
Dark Blaes,	2	8
Sandstone, hard,	1	9
Do., extra hard,	0	6
Dark Fakes,	6	9
Fakes and Sandstone Ribs,	3	0
Fakes,	0	2
Sandstone,	1	3
Fakes,	3	10
Sandstone, hard,	0	6
Fakes,	0	9
Total depth of Bore to 31st December, 1887,	611	6

This bore was executed by Messrs. John Henderson & Son, mineral boring prospectors and Artesian well engineers, General Terminus, Paisley Road Toll, Glasgow, between the months of August and December, 1887.

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No. XV.—On Mammalian Remains from Cresswell Crag Bone Caves. By Professor John Young, F.G.S., *Hon. Member.*

[Read 13th March, 1890.]

The specimens exhibited are the first from the Cresswell district which have come into my possession. Several fragments are not yet identified, but those shown are sufficiently distinct. They are:—*Hyæna, spotted*, fragment of adult upper jaw; *Rhinoceros tichorhinus*, ulna; *Reindeer*, portions of two horns; *Horse*. For comparison I show the skull of a Hyæna from the Andersonian collection, and the difference of proportions will be seen by inspection.

The bones belong to that second stage of the Cresswell fauna posterior to the presence of the Hippopotamus. The caves have been described by Mello and Dawkins in the *Quarterly Journal of the Geological Society*, and a summary of the story is given by Dawkins in his "Early Man in Britain."

The traces of man in this region are of the cave man, and of the river-drift man, his predecessor and his inferior in cultivation. This order of succession is no doubt true for individual localities, the implements of the ruder people being found in layers below those in which the better shaped flints are found. But as yet the evidence of a race distinction between the two is unsatisfactory, and there is much in favour of Mr. Evans' view that the two men belonged to the same race and the same time. A singular flaw in the reasoning on this subject is betrayed in the oft-repeated statement that the cave man presented everywhere in Europe the same grade of civilisation, it being obviously assumed that each of the two peoples came on a distinct wave. It is further assumed that the duration of the Pleistocene age was of vast extent, and that thus there was ample time for the separate migrations. But this is a wholly arbitrary assumption. I shall immediately refer to the question of time. Meanwhile let me say that the passage of one race across Europe, be it from east or south, must have been gradual, and that as each horde moved from its ancestral home, mere lapse of time (not necessarily of *long* time) would add to the resources of the people. The gradual improvement of the conditions is a postulate of the Pleistocene history, and it is contrary to our belief in the capacities of the race that civilisation should follow epochs in time instead of conforming to the circumstances

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which rendered improvement possible. But it is the time problem to which these interesting relics have tempted me to address myself for a few minutes.

As a zoologist I have long doubted the extreme antiquity usually assigned to palæolithic man, an antiquity which really rested on the ascription of each type of culture to its own epoch. Though not prepared to assert that man existed in Miocene ages, I have for several years taught that there is nothing inherently improbable in the supposition that negative evidence—that of the absence of his remains—was not conclusive. Sharing the belief that man migrated northward and westward from some more favourable nursery which, seventeen years ago I thought and still think, was in some tropical South Asiatic area, it seemed a necessary consequence that the pioneers were less civilised, less expert in the methods of comfort, than those who followed after them. In point of time, therefore, the western rudeness of life might be coeval with a better cultivated style of existence in the east. I had, therefore, not knowing of Mr. Evans' conclusions, advanced the opinion of the contemporaneity of the palæolithic and neolithic man. But what was then hesitatingly advanced, for the burden of great names (and let me add weighty censure of scepticism) was on the other side, was that this view forbade acceptance of the ancient doctrine that the first west European race had appeared eighty or a hundred thousand years ago. To have gained so much at so early a date, and to have stagnated for an immense lapse of centuries, was contrary to my zoological belief. Anatomy might require vast time (though I don't believe that either) for its modification, but that mental endowment, the capacity to improve his position by taking advantage of everything favourable in his surroundings, should be in abeyance for enormous periods, that seemed to be incredible and unsupported by trustworthy evidence.

It was therefore with great satisfaction that I read Professor Prestwich's paper in the *Quarterly Journal*, vol. xliii., and his more recent statement of belief in his great work on geology. Particularly admissible is his argument regarding the civilisation of the east, which, when we first come to know of it, 5000 years B.C., was already very high, and which, therefore, required a still more remote antiquity for its commencement. Prestwich does not think the limit of man greater than 20,000 or 30,000

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years, and though he expressly says these are not precise figures, they represent fairly well a tangible estimate by which we can plumb the past. It is entirely in accordance with the views of those who accept the known facts of man's progress in historic times as proof of man's gradual improvement so long as he is in fairly favourable conditions. Shut in in a country enervating by reason of its tropical heat or numbing by its severe cold, there may be neither inclination in the one case nor opportunity in the other to struggle against his fate. What he has he keeps, and lives like a lotus eater in the tropics, or a semi-torpid machine on the shores of Greenland. But in Europe it was very different. There was everything to stimulate, nothing to unduly depress. Hence I have no hesitation in stating my belief that, for aught which has been asserted to the contrary, these bones and the men who saw their living possessors *may* have been the contemporaries of the incipient civilisation which, according to the latest researches, branched off to the north-east towards China, to the east to the Euphrates.

I append a note of the localities from which other specimens in the Hunterian Museum were derived :—

1. From the Kirkdale Cave. Specimens without precise locality given by Dr. Buckland to Dr. Brown of Lanfine.
2. From the Rock Shelter at Hunterston, given by Mr. Cochran-Patrick.
3. The Dusk Water specimens, given by Mr. John Smith, Kilwinning.

These are laid out in the Museum, and will well repay a visit by members of the Society.

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No. XVI.—On Things New and Old from the Ancient Lake of Cowdenglen, Renfrewshire. By James Bennie, of the Geological Survey of Scotland.

[Read 10th October, 1889.]

For several years before I left Glasgow, in 1868, one of my favourite resorts for fossil-hunting was Gameshill, in the parish of Dunlop, Ayrshire. It was reached by railway to Crofthead, and thence by road through the pass in the Ferenezc hills to Lugton, and onward by the Stewarton road—in all about 8 miles beyond the railway. The scenes passed on the way were often the chief attractions of my visits, the aspects of the hillsides and of the bright sheet of Lochlibo at the head of the glen, which varied with the seasons, giving me much pleasure at the time, as well as in after recollection when I contrasted them with the hard and dry scenes of my daily life in Glasgow.

In 1867 other attractions were, however, added. The glen had been chosen as the best route for a direct railway to Kilmarnock, and so through the workmen's operations became nothing more than a long quarry with all its uncouth sights and sounds. But my consequent anathemas were suddenly changed to blessings on the Fair Saturday of July, 1868, when I found the navvies busily engaged in cutting through a bed of clay and peaty mud, bringing back to the light of day the remains of a long-buried Lochlibo. This deposit had evidently been laid down in a deep lake formed by a ledge of rock which stretched across the glen and which the workmen had cut through before reaching the clay. Samples of this clay which I took showed plant remains. Hearing that the "forehead of an old cow" had been got in it 25 feet below the surface a few days previously, I called on Mr. Orchur, the overseer, who showed me what was really a skull of *Bos primigenius*. I took the following measurements:—across forehead, 11 inches; round base of horn, 13 inches; length of perfect horn, 30 inches; length of broken horn, 6 inches.

On 29th August I revisited Cowdenglen, chiefly because Mr. (now Dr.) James Geikie considered, as I learned from Mr. Croll, that the drift overlying the lake-beds was Boulder-clay as certainly as that the drift which lay below them was Boulder-clay. I then satisfied myself that, as the overlying drift was Boulder-clay (being full of striated stones, the best test I know of), the mud in

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which the skull was found must be interglacial. I took a sample of the laminated lake-beds where they thinned out against the bank of Boulder-clay, finding it to be full of vegetable débris, such as stems of mosses and plants, and various seeds.

On 22nd October I again took samples of the clay-beds, giving portions to (the late) Mr. James Mahony, who found that about one-third of their bulk consisted of diatoms, the balance being largely remains of other organisms, animal and vegetable.

Again, in November, with Mr. Mahony and (the late) Mr. James Coutts, long a member of this Society, I paid another visit to the old lake, taking further samples, while Mr. Mahony sketched examples of crumpling in the lake-beds.

In December, 1868, I left Glasgow for Survey work in Edinburgh, and so missed a further exposure of the beds which took place in 1869, when a great landslip necessitated extensive excavations. But from reports sent me by various observers I was able to fairly follow the course of events.

In July, 1870, when on Survey work in Paisley, I made four further visits, one with Mr. R. L. Jack (now in Australia), taking fresh samples of the mud-beds, and finding a mammalian bone* lying under some of the beds still undisturbed, near the farm bridge over the railway between the two lakes, and near the western end of the east lake, in which bones of the elk, ox, and horse were found, as recorded by Mr. Robert Craig. This portion of the lake-beds consisted of layers of fine gravel and mud, about 5 or 6 feet deep, and it was evident that the bone which I found had fallen from one of the gravel layers. In these layers fragments of the upper peaty beds had occurred as waifs, and one of these I lifted and washed, finding in it several seeds identical with those in the solid mass of the upper peat-beds.

The first public notice of these lake-beds was given by Professor James Geikie (*Geol. Mag.*, Sept., 1868). Mr. Craig (Oct., 1868) expressed doubts as to the upper bed being Boulder-clay chiefly because it seemed to him to be lighter in colour and more gravelly than the lower bed, which was dark in colour, and compact and hard in consistence.

After heavy rain in the autumn of 1869 the mud of the lake-beds quickened and a landslip occurred near the north end of the east lake, bringing down part of the upper beds and the overlying

* See page 225, under *Mammalia*.

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Boulder-clay, and disclosing the lower Boulder-clay standing up behind the lake-beds and between them and the rocky bank of the hollow. At first it appeared as if this settled the question as to the origin and character of the upper bed by showing it to be slipped stuff from the hillside above the hollow in which the clay-beds lay, and if that was so then Mr. Geikie's inference as to a second glacial period was wrong. In passing I may state that this theory dissipates entirely the doubts expressed by Mr. Craig as to the upper bed being Boulder-clay the same in origin and character as the lower one, but simply misplaced by landslips.

In the *Geological Magazine* for February, 1870, Mr. James Geikie discussed the landslip theory, and showed by diagrams that the gradients of the hillside above the hollow in which the lake-beds lay were such that it was impossible for Boulder-clay to slip down along them even to a small extent, far less bodily, as it must have done if it slipped at all, for there is now no Boulder-clay remaining on the hillside.

On 11th November, 1869, Mr. Craig read a paper to this Society (*Transactions*, vol. iv., p. 17), giving his final judgment on the whole question, and as he had the advantage of seeing the landslips and the subsequent excavations I may quote the dimensions he gives of the upper Boulder-clay, the only one in dispute. "A small boss [mass] of it [the upper Boulder-clay] overlies the stratified beds on the west end of the western beds, and another small boss [mass] of it spreads over the divisional boss of lower boulder-clay, overlapping the ends of the stratified beds on both sides of it. . . . The small boss [mass] lying on the west end of the western beds has a length of 300 feet, and a thickness of 8 feet in its greatest depth. The other boss [mass], which spreads over the divisional boss of lower till and overlaps the end of the stratified beds resting upon it, has a length of 600 feet and a depth of 3 to 10 feet."

These "stratified beds" lay in two basins or hollows in the lower Boulder-clay, separated by a hillock of the same material, which had a length of 450 feet, and stood 8 to 10 feet above the upper stratified beds, stretching across the valley from side to side. The amount of the overlap of the mass of the upper Boulder-clay over the ends of the stratified beds is not given by Mr. Craig, but as the hillock of the lower Boulder-clay extended only 450 feet, while the upper Boulder-clay extended 600 feet, that gives

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an overlap of 150 feet. Nor are we informed whether the upper Boulder-clay was equal on both sides, or whether there was more on one side than the other. Here, then, we have the testimony of Mr. Craig as to there being two masses of Boulder-clay lying upon the stratified beds, which could not result from a landslip, but only from regular deposition. He says that slips of Boulder-clay had taken place during the deposition of the lake-muds and peats in the eastern lake, but on reading his remarks carefully it will be found that these slips took place during the time when the lower half of the stratified beds in that lake were in the course of formation, and so have no reference to the upper Boulder-clay, which was a later and quite independent deposit made after the lake-beds were completed. This is clearly proven by what is said by Mr. Craig about the western lake-deposits, that they consisted of sand, gravel, and mud, the mud being very fine and entirely free from stones. The cutting into them was 15 feet in depth, but probably the entire depth was more than double that, while so far as the beds were seen, *no slips of Boulder-clay had run into them*, mixing itself with the soft mud, and in all other respects the stratified matter in it was identical with that in the eastern lake.

The source of the Boulder-clay which Mr. Craig speaks of as having slipped into the eastern lake during its earlier existence must therefore be sought for in the cliff of lower Boulder-clay which was found standing up between the lake-beds and the rocky wall of the hollow in which the lakes lay, and not in the hillside above the hollow, where, as Mr. James Geikie shows, there is now no trace of Boulder-clay.

As Mr. Craig's paper, though read in November, 1869, was not published till 1871, I had not the benefit of his observations when I visited Cowdenglen in 1870. The following extract from a letter which I wrote to Mr. James Croll on 16th July, 1870, will show that I had then arrived at the same conclusion as that which I have since drawn from a perusal of Mr. Craig's paper:—"From all I saw it was clear that the great noise made about the landslip of 1869 having set the matter to rest, by dispelling entirely the idea of a second glaciation, was much ado about nothing, the whole case, as I understood it before the landslip, being quite unaltered by it. Doubtless in some respects opposite the glaciated crag (at the north end of the eastern lake) the lower

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Boulder-clay rises up from under the lake-beds and has formed the bank of the lake at that end, and from it slips may have taken place repeatedly during the existence of the lake, but that is all; the greater part of the cutting reveals what is undoubted Boulder-clay lying in a true position upon the lake-muds, and it was upon this Boulder-clay that all the conclusions were drawn, and they remain as solid and true as before. Such is the idea I formed from what I saw."

This is amply confirmed by the quotation I have made from Mr. Craig's paper, namely, that two masses of Boulder-clay, one 300 feet in length and 8 feet thick, and the other 600 feet in length and from 3 to 10 feet thick, lay upon the lake-beds, which Mr. Craig believes to have been deposited by water-borne ice at a period long subsequent to the final deposition of the lake-beds; and, of course, there can be little doubt that the lake-period was in times which we are accustomed to call interglacial. The only difference now between Mr. Geikie and Mr. Craig is that the latter believes the upper Boulder-clay to have been formed by water-borne ice or icebergs.

But if the facts given by Mr. Geikie and Mr. Craig are not considered sufficient to prove the upper Boulder-clay to be the result of deposition in the ordinary sense and not slipped stuff, there are other circumstances which place the lake and its peats and muds so close to the glacial period as to amount to contemporaneity with its later stages. These facts were briefly alluded to by Mr. Mahony (*Geol. Mag.*, 1869, p. 390), but what I suggested then to him I may repeat now, as it seems to me to be conclusive as to the extreme antiquity of the lake-beds and their contents.

As already stated, these lake-deposits lay partly on an earlier Boulder-clay, which was seen standing up as a hillock separating them into two basins and was also seen cropping up on the north side of the east lake; but on the south side of that lake the mud-beds lay directly upon and against a finely-glaciated surface of trap-rock, and upon that evidence of ice-action I found my argument for the extreme age of the lake and its silts.

On my visit in July, 1868, the most conspicuous, and to me most attractive, object visible was a cliff of dark red porphyrite on the south side, intensely glaciated, having on its surface small *roches moutonnées*, and striæ coarse and fine, its general surface

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being highly smoothed and polished. A hollow indentation lay along the base of the cliff, and the projecting ledge above it was glaciated also. From the direction of the striæ, and, still more, from the southern faces of the small eminences on its surfaces it was clear at a glance that the ice which had glaciated this rock came from the south-west, that in passing down the glen it had encountered the ledge of rock which, from the base of the cliff, stretched across the glen, and that it had been dammed back by the ledge till it reached the top, when it passed over and escaped down the glen which slopes rapidly to Crofthead.

This glaciated rock-surface had been covered by the lake-mud up to a certain height, as was proved by portions of the mud found still remaining in crevices when I visited it. The upper part of the cliff and the hillside above it, which had not been protected by the lake-silt, were splintered and shattered through exposure to the weather.

Now, my argument for the antiquity of the lake and its silts is that if the base of the cliff had not been protected from the weather immediately after the final passing away of the ice it would in a very few years have lost, first the polish of the surface, next the finer striæ, and then the deeper ones. But even before the effacement of these had proceeded very far, the rock, especially at the overhanging part, would have cracked and splintered through the natural changes of the weather. This actually took place in the very short time which elapsed between the uncovering of the rock and the laying of the permanent rails, *i.e.*, two years or thereby. It follows from the fact that the drainage water of the glen, which, like the ice itself, would be dammed back by the barrier of rock, would rise to the same level that the ice reached, and would protect the rock from disintegration.

Thus we have proof that the lake was formed immediately after the passage of the ice, and of course the deposition of the mud would begin almost at the same time, and probably at first at a comparatively rapid rate, the drainage area being soft and without any covering vegetation. But afterwards, as the ground became firmer and more clothed, denudation by rain would be retarded and the deposition of mud would become slower, till finally the last stage would be reached in the formation of peaty sediment, one-third of the bulk of which consisted of the slowly-elaborated frustules of diatoms.

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It may naturally be asked why I have allowed twenty years to elapse before offering these observations and exhibiting the various organisms found in these old deposits. As already stated, I washed some of the peaty silts in 1868 and early in 1869, and partially examined them, but feeling I could not make so much of them as Mr. Mahony could do, I laid them aside. In the summer of 1888 I learned that Mr. Clement Reid intended to trace the history of our present British Flora back into Pleistocene times, so I hunted up my old gatherings from various quarters and submitted to him everything which seemed to be of vegetable form or structure. In an admirable paper on the Pleistocene Flora (*Annals of Botany*, Aug., 1888) Mr. Reid catalogued eleven seeds as having been recognised by him in my Cowdenglen gatherings. I afterwards recovered some more of my gatherings of 1868 or 1870, and from them Mr. Reid has added twelve other seeds.

Besides the seeds other organisms were unnoticed by Mr. Mahony, and as these are interesting in many ways I thought that a re-statement of the circumstances of the discovery of the old lake and a catalogue of the old and new finds might be placed before the Society, not only to complete, so far as investigation has as yet gone, the life-phenomena of the old lakes, but also to show what may yet be done in a direction seldom taken—the examination and study of old inland lake-peats and silts.

As regards the organic remains found in these investigations, Mr. Mahony (*Geol. Mag.*, 1869, p. 390) gave the results of his minute examination of the lake-silts of Cowdenglen, in which he enumerated three species of desmids; thirty species of diatoms; eleven species of mosses; nine species of plants, represented by twigs, leaves, and seeds; one species of sponge, represented chiefly by spicules; one species of crustacea, represented by what seemed to be a larval form of *Daphnia;* thousands of fragments of clear yellowish animal tissue which he thought were the remains of a soft-shelled entomostracan; and many remains of insects, represented by numerous elytra and mandibles of beetles, of at least three species—in all fifty plants and eight animals, an exceedingly creditable number to be determined by one observer.

Next, Mr. Craig (*Transactions*, vol. iv., p. 17, 1871), besides *Bos primigenius*, first recorded by Mr. James Geikie, added *Megaceros Hibernicus* and *Equus caballus*, the first represented by part of a horn and the second by a few bones. He mentions, besides, eight

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plants identified from branches, twigs, leaves, and bark, seen in his examination of the lake-beds, but of course he made no special or exhaustive search for such things as had been done by Mr. Mahony.

Lastly, Mr. David Robertson, in the lower clay beneath the peat-beds, found ten species of freshwater Ostracoda, as is recorded in the Monograph of the Post-tertiary Ostracoda of Scotland, (Palæontographical Society, 1874).

Mr. Mahony records that he found spicules of a freshwater sponge occurring frequently—indeed in every slide. As I did not examine the dust of my washings with a microscope I cannot say the same; but the objects Mr. Mahony supposed to be "the eggs of an insect, one of the ephemera," were pronounced to be the eggs of sponges by Dr. G. J. Hinde, who, in a letter to Mr. Reid says—"The bodies are the gemmules of freshwater sponges, otherwise known as the statoblasts or winter eggs. They belong to the two common species—the larger to *Spongilla lacustris*, Linn., which has smooth skeletal spicules, and curved spined acerate spicules of the gemmule — the smaller to *Meyenia* (*Spongilla*) *fluviatilis*, Auct., which are furnished with minute amphidisci, or spool-like spicules with radiate ends."

Subsequently, in a letter to myself, Dr. Hinde says—"I am glad to have the chance of seeing that the gemmules of freshwater sponges are capable of preservation in the fossil state, which, as far as I am aware, has not yet been recorded. The sponges themselves are disintegrated by the end of the season, and resolved into their constituent spicules; but the gemmules, being provided with an inner chitinous layer surrounded by a layer of spicules, are strong enough to endure transportation and preservation. There is hardly any difference to be noticed in these fossil minute spicules from those of existing species. They belong to the only two species of freshwater sponges which now occur in Britain, and it is very interesting to find them mingled together in the Cowdenglen material. The supposed 'midges' eggs' you sent last are really small groups of the gemmules of *Spongilla lacustris*. It is not at all uncommon to find them grouped in this manner, not unfrequently attached to the surface of stones, rocks, or pieces of wood."

A great number of round flat bodies which appeared in some of the washings seemed so like lycopod spores that I at first

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supposed them to be such, and submitted them to Mr. Reid, but he, failing to recognise them, showed them to Dr. Hinde, who, by the assistance of Mr. Kirkpatrick of the British Museum, found them to be in reality the gemmules or statoblasts of a freshwater polyzoön, *Cristatella mucedo*, Cuvier. "This is," says Dr. Hinde, "a form which, according to Allman, is pretty generally distributed in England, Scotland, and Ireland. It is the only British freshwater form which has the statoblasts furnished with hooked spines, all the others being smooth. These statoblasts appear to be of a chitinous character like those of freshwater sponges, and they are similarly set free when the organism is broken up at the end of the season."

Such are some of the new things which I now wish to add to the record of Cowdenglen, and I hope they will justify this attempt to revive and increase the interest felt in these old lake-deposits, and in the times and conditions under which they were formed.

Those times and circumstances I may in conclusion briefly recall, as they were originally disclosed to us in the exposures made by the railway excavations, and in the examinations of the portions of the old lake-silts. In the lowest parts of the lake-deposits exposed we had a fine brick-clay, in which only clay nodules were noticed. In the clay immediately above occurred the ostracoda as recorded by Mr. David Robertson. Next came the lower peat-bed in which were the spicules and winter eggs of sponges and polyzoa identified by Dr. Hinde, also various seeds and mosses, with fragments of the chitinous coverings of *Daphniaæ*. Lastly, the upper peat-bed in which were found other seeds and mosses and frustules of diatoms.

The times and circumstances represented by the different deposits consist, first, of the great glacial period, during which was laid down the lower Boulder-clay. Some writers think that this period was of short duration, simple in its course, and somewhat monotonous in its phenomena. A great sheet of ice covered the whole land to a great depth—2000 feet or more—in an unbroken mass, slowly moving outwards all round from the highest watersheds, grinding down the rocks it passed over, carrying with it all the débris made or gathered in its progress, and either dropping it here and there or delivering it at the ice-foot in a terminal moraine.

But was the glacial period short and simple in its course and

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phenomena? I humbly think it was not, and that here in Cowdenglen, as in many other places, we have proof that it was long in time and varied and complex in its phenomena. The first proof that we have of this complexity is the diverse directions of the striæ in the district. Mr. James Geikie (*Geol. Mag.*, 1869, vol. vi., p. 74) says that further examination of the striæ had convinced him that instead of one set of striæ, as mentioned in his first note (*Geol. Mag.*, Sept., 1868), there are three sets. "The common direction of the ice-scratches in that neighbourhood is from about north to south, and the Lower Boulder-clay contains fragments of gneiss, mica-schist, granite, and other north country rocks. . . . The prevailing movement of the ice which deposited the Lower Boulder-clay must therefore have been from N. to S., but in the Cowden Valley there is evidence of a movement in the opposite direction. The knob of trap-rock, against which the *Bos*-beds have been deposited, is glaciated *down*, *i.e.*, north-east, and not *up* the valley as stated in my note. An older and much fainter set of striæ (the direction of which is not apparent, but may be either up or down the valley) are nearly obliterated by the later set; while on the north side of the valley above the railway cutting, and quite close to Crofthead, the rocks are glaciated *up* the valley, or towards the S.W. Similar appearances have been noticed elsewhere, showing that the ice-streams from the various centres of outflow sometimes prevailed the one against the other."

These striæ, pointing in opposite directions in exactly the same place, prove movements in the ice-sheet which were not simultaneous, but consecutive—a before and after movement. The cause of such changes is not manifest but conjectural, say, in a decrease in thickness of the ice-sheet, which allowed local gravitation to come into play, and lower hill-ranges to determine or divert the outflow of the lessened ice-sheet, which, when thicker, over-rode them. We may therefore infer that the south-pointing striæ on the hillsides above Cowdenglen were made in the earlier stages of the glacial period by a very thick mass of ice which, impelled by the force that drove it outwards from its centre of dispersion among the highest hills in the North Highlands, had an impetus sufficient therefrom which enabled it with ease to over-ride the Ferenezc hills, and pass out to sea over the lower grounds of Ayrshire. The striæ pointing N.E. on the glaciated crag on the east side of Cowdenglen were made in one of the later stages of

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the glacial period by a lesser mass of ice whose centre of dispersion lay amongst the highest ridges of the Fereneze hills, and which flowing northwards down Cowdenglen passed into the sea over the lower parts of Clydesdale.

The lake-deposits prove a very great change indeed during the time of deposition of their 60 feet of thickness, and represent, in the varied character of the different beds and the organisms found in them, a lengthened period of time. The ice had passed entirely away, vegetation had entered and possessed the land, clothing the Fereneze hillsides with a flora as luxuriant as that of to-day, and capable of affording sustenance to at least three of the large animals of the latest Tertiaries:—The gigantic *Bos*, to which our Ayrshire kye seem dwarfs; the great elk with its regal crown of horns; and the small horse, of no great presence in itself but with capabilities of expansion into the big Clydesdale of to-day.

In the later lake-silts and peats, crowded as they are with stems and seeds of mosses, sedges, and pondweeds, with one-third of their whole bulk composed of diatoms, we see a long period of quiet typified by the present Lochlibo. In the upper Boulder-clay we have a return of glacial conditions, with ice again dominating land and water, spreading a drift-wrack of striated stones and glacial mud, in perhaps a fugitive and patchy manner, over the lake-beds and burying them from the light of day, till in these latter days they are brought to light by the railway navvy's pick and shovel.

Such is my story of the ancient lake of Cowdenglen as I now understand it, and I deduce from it a moral which I commend to the attention of my fellow-members of the Geological Society of Glasgow—"Put not off till to-morrow what can be done to-day." If I had taken advantage of the opportunities which lay to my hand in 1868 and 1869 of searching these old deposits as thoroughly as I have examined the remains from them still accessible to me in 1888 and 1889, the results would, I am confident, have been greater by a hundredfold than they now are.

Notes on Organic Remains from Cowdenglen.

Coleoptera. — Remains of beetles frequently occurred in the upper part of the lake-bed, but in a sadly disjointed state, though otherwise well-preserved. They consisted chiefly of elytra; but

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limbs and segments of bodies also occurred. Mr. C. O. Waterhouse of the British Museum kindly looked over my gatherings, and said—"I feel sure many of the pieces might be identified by a coleopterist who has a little time to devote to them"; and of one form he remarks—"I feel sure it is a *Donœia*; at least I cannot think of anything else it can be, but we know of no species to which it can be referred." Of the others he recognised as follows:—

1. *Geodephagus*, probably *Pterostichus*, portions of elytra.
2. *Donacia*, sp.
3. *Auchemenus*, sp.
4. *Patrobus excavatus*, pronotum.
5. *Ilyleias angustior*, or closely allied species, pronotum.
6. *Acarus*, var. *falumnus*.

Caddis cases occurred, apparently belonging to four or five species, as they differed in the material of which they were built, and also in the style of architecture adopted. Some were built up of grains of sand imbedded in a network of pores, others had seeds and even pieces of beetles plastered on the outsides of the walls of the cases, and one was made up of vegetable fibres arranged like a piece of wattle-work.

Crustacea.—Though Mr. David Robertson has published ten species of ostracoda from the lower part of the lake-bed, which was composed of pure clay, none occurred in the upper part, owing, as he suggested, to the presence in the peaty silt of carbonic acid, which he found sometimes in quantity sufficient to redden litmus paper. This theory seems confirmed by the extraordinary abundance in this bed of the chitinous substance forming the coverings of *Daphnia*, which from its nature carbonic acid cannot affect. The quantity of these mica-like scales was so great sometimes as to cover the bottoms of my sieves to the thickness of a quarter of an inch. Thence we may safely conclude with Mr. Mahony "that the animals themselves existed in myriads during the deposition of the bed." Mr. Thomas Scott, naturalist to the Scottish Fishery Board, tells me that in silt similar to that of Cowdenglen, which he dredged from the bottom of Loch Ness at a depth of 129 fathoms, he found a like abundance of *Daphnia* scales. The epiphnia or winter eggs of *Daphnia* also occurred frequently in the same part of this ancient lake.

Mosses.—A good many fragments of mosses turned up in the

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various washings of the upper silt-bed. Through the kind offices of Mr. Robert Kidston, F.R.S.E., they were submitted to Mr. Charles P. Hobbkirk, who has been able to determine four species, viz.:—

Hypnum cordifolium, Hidu.
Polytrichum subrotundum, Huds., or *P. aloides*, but probably the former.
Amblystegium serpens, Linn.
Brachystegium salebrosum, Hoffm.

Flowering Plants.—Seeds of the following twenty-eight species were determined by Mr. Clement Reid, F.G.S.:—

Ranunculus aquatilis, Linn.
Ranunculus flammula, Linn.
Papaver somniferum, Linn.
Viola, sp.
Montia fontana, Linn.
Rubus idæus, Linn.
Poterium officinale, Hook.
Hippuris vulgaris, Linn.
Myriophyllum spicatum, Linn.
Menyanthes trifoliata, Linn.
Pedicularis palustris, Linn.
Galeopsis tetrahit, Linn.
Ajuga reptans, Linn.
Polygonum lapathifolium, Linn.
Rumex crispus, Linn.
Betula alba, Linn.
Corylus Avelana, Linn.
Salix repens, Linn.
Pinus sylvestris, Linn.
Alisma plantago, Linn.
Potamogeton perfoliatus, Linn.
Potamogeton pusillus, Linn.
Potamogeton pectinatus, Linn.
Scirpus lacustris, Linn.
Scirpus pauciflorus, Lightf.
Carex rostrata, Stokes.
Isoetes lacustris, Linn.
Chara, sp.

Mammalia.—The bone referred to at page 214 was submitted to Mr. Simpson, assistant to Professor Turner, and he, by comparison with a skeleton in the Anatomical Museum of the University of Edinburgh found it to be the third left side rib of a horse not larger than a pony.

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PROCEEDINGS FOR SESSION 1888-89.

(31ST SESSION.)

SOCIETY'S ROOMS, 207 BATH STREET, 11th OCTOBER, 1888.

Mr. WILLIAM JOLLY, F.G.S., *Vice-President*, in the Chair.

Mr. ROBERT DUNLOP exhibited specimens of Altered Intrusive Dolerite, the "White Horse" of the miners, from the Lanarkshire coalfield; also Plant remains from the Airdrie district, including *Cyclothea* (a new genus), *Lepidodendron Peachii*, *Cordaites*, sp., leaves and stem. Remarks on the dolerite were made by Messrs. John Young, F.G.S., Sommerville, Blair, F.G.S., and other members. It was stated that in mining phraseology altered columnar coal was known as "Black Horse."

Mr. JAMES B. MURDOCH, F.R.Ph.S.E., *Honorary Secretary*, exhibited a specimen of a rare fossil crustacean, *Prestwichia rotundata*, Woodward, found in Carboniferous Shale near Stevenston, Ayrshire. Unlike its congeners, the Trilobites and Eurypterids, this form is still represented in recent seas by the nearly-allied King- or Horse-shoe Crab. It has only been found previously in Western Scotland near Kilmaurs. Its occurrence in the present locality is another proof, if one were needed, that the fresh-water or brackish-water strata of the Upper Coal Measures are prolonged westwards. The Kilmaurs specimen was described and figured in the *Transactions*, vol. ii., part 3, page 241.

Mr. DUNLOP said that when Mr. B. N. Peach of the Geological Survey was identifying some fossils from strata near Airdrie he had found and named an imperfect example of this rare limuloid form.

Mr. JAMES WHITE, *Honorary Librarian*, read a paper entitled "Notes on Gairloch, Ross-shire." [See p. 192.] The paper was illustrated by diagrams and by specimens of the rocks of the district. A discussion followed, remarks being made by Messrs. Dugald Bell, R. J. Steele, John Young, F.G.S., M'Lennan, and the Chairman. The latter said that, as the author had not exhausted the subject, he should give his further notes to the Society, and mentioned incidentally that the word "Archæan," as applied to the northern rocks, was unfortunate, as expressing finality, and that "Hebridean" was a much more appropriate and acceptable term.

The CHAIRMAN said further that, as he would not again occupy the chair owing to demission of office, he would take the opportunity of thanking the members for their appreciation of his occasional papers. He hoped that

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the Society would continue to prosper, and urged the necessity of members making a continuous effort to increase the membership roll, which every year was being reduced by death and resignations from various unavoidable causes.

SOCIETY'S ROOMS, 207 BATH STREET, 8TH NOVEMBER, 1888.

(ANNUAL GENERAL BUSINESS MEETING).

Mr. DUGALD BELL, *Vice-President*, in the Chair.

The HONORARY SECRETARY (Mr. Murdoch) read the Report of the Council for the past year. Mr. John Wight, C.A., *Hon. Treasurer*, read the Financial Statement, and Mr. James White, *Hon. Librarian*, submitted his Report on the Library.

Mr. DAVID FORSYTH, M.A., proposed that a hearty vote of thanks should be awarded the standing officials for their services on behalf of the Society. The motion was seconded by Mr. Joseph Sommerville, and unanimously agreed to.

The election of office-bearers was then proceeded with :—

Mr. JOSEPH SOMMERVILLE was elected Vice-President, and Messrs. William Armour, C.E., William Jolly, F.G.S., James S. M'Lennan, and Robert J. Steele, Members of Council.

Mr. JOSEPH SOMMERVILLE, *V.P.*, proposed, and Mr. David Forsyth, M.A., seconded a motion that the death of Dr. William Wallace, F.C.S., should be noted in the minutes, and that an expression of regret for his loss should be sent to Mrs. Wallace. Dr. Wallace had been for a number of years a member, and though this direct connection had latterly ceased, he had on several occasions contribut papers to the Society.

Mr. JOHN YOUNG, F.G.S., exhibited specimens and sections of a variety of Osmund Stone, a volcanic tuff, enclosing Pearl Sinter or Perlite, from Corrieburn, Campsie, and read some notes upon the subject.

SOCIETY'S ROOMS, 207 BATH STREET, 13TH DECEMBER, 1888.

Mr. JOSEPH SOMMERVILLE, *Vice-President*, in the Chair.

Mr. WILLIAM CULLEN, teacher, 4 Catherine Street, N., and Mr. Duncan Macintyre, M.A., teacher, Cedar Cottage, Alexandria, N.B., were elected Ordinary Members.

The HONORARY SECRETARY (Mr. Murdoch) read, on behalf of Mr. Robert Craig, *Cor. Member*, Beith, a paper entitled "Notes upon a Cutting in the New Kilbirnie Branch of the Lanarkshire and Ayrshire Railway on the Farm of Gurdy, Beith." [See page 64.]

At its close remarks were made by Mr. John Young, F.G.S., and Mr. James Thomson, F.G.S., the latter observing that a point of great interest referred to by the author was the great break in the succession of the strata, which extended through Ayrshire and Renfrewshire to the confines of Lanarkshire. Mr. Thomson said that Mr. Craig might be asked to extend his remarks upon the non-occurrence of the thick-bedded limestones

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in the locality. He held that the igneous rocks of the district belonged to a period extending from the Lower to the Middle Carboniferous formations, and on this point the Geological Survey maps of the district were entirely wrong.

Mr. JAMES S. M'LENNAN read a descriptive paper on "The Geology of the Lugton Valley.' [See page 91.]

At its close an interesting discussion was taken part in by Messrs. Young, Thomson, Miller, D. Bell, and the Chairman.

SOCIETY'S ROOMS, 207 BATH STREET, 10TH JANUARY, 1889.

Mr. DANIEL M'MILLAN, *Vice-President*, in the Chair.

Dr. Samuel Sloan, M.D., &c., 1 Newton Terrace; Rev. Alexander Simpson, B.A., B.Sc., F.G.S., 46 Princes Square, Strathbungo; Mr. William Brown, merchant, 22 Westminster Terrace; and Mr. James A. S. Little, M.A., teacher, Elgin Terrace, were elected Ordinary Members.

Mr. WALTER BURNS exhibited specimens of Intrusive Dolerite from Loch Ranza, and Sandstone with Dendritic Markings from John o' Groats, Caithness. Mr. D. C. Glen, F.G.S., exhibited a number of specimens of Sandstone, Slate, and Flint showing the same curious forms, and an interesting discussion as to their origin and occurrence followed.

Mr. JOHN YOUNG, F.G.S., exhibited, under the Society's microscope, several sections of a small hydrocoralline organism new to Western Scotland—*Mitcheldeania Nicholsoni*—found in limestone at Trearne, Beith. He said that it had been named *Mitcheldeania*, having first been found, by Mr. E. Wethered, F.G.S., in the limestone at Mitcheldean, in the Forest of Dean, some three years ago. It had now to be recorded as occurring at Trearne, Beith, Ayrshire, where it is found, somewhat sparingly, in one of the thin polyzoal bands of the limestone. Mr. Young described the minute structure of the organism, which somewhat resembles that of Millepora, one of the Hydrocorallinæ, but having smaller tubes and a more dense wall-structure than is found in the latter. Two species of *Mitcheldeania* have now been found in the Carboniferous limestones of Scotland, viz., *M. Nicholsoni* and *M. gregaria*, but the specimens exhibited are its first known occurrence in any of the western districts.

Mr. MATTHEW BLAIR, F.G.S., read a paper on "The Surface Geology of Paisley," [see page 139], illustrated by diagrams and specimens of rocks and fossils. A horn of *Bos primigenius*, found in the neighbourhood at a depth of 14 feet, was also shown. Remarks were afterwards made by Messrs. John Young, F.G.S., James Thomson, F.G.S., D. C. Glen, F.G.S., Steel, and the Chairman.

SOCIETY'S ROOMS, 207 BATH STREET, 14TH FEBRUARY, 1889.

Mr. DUGALD BELL, *Vice-President*, in the Chair.

Mr. HENRY M. CADDELL, B.Sc., F.R.S.E., *Honorary Secretary* of the Edinburgh Geological Society, read a paper entitled "Recent Advances in the Study of Mountain-building, with special reference to the Structure of

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the North-west Highlands." He explained that amongst most of the geologists who of late years had been engaged in investigating the structure of the N.W. Highlands, and especially those of them who did not concur in Sir Roderick Murchison's explanations of the phenomena exhibited there, there was a growing belief that great overthrusts had been largely instrumental in producing the remarkable stratigraphical relations of the rock masses of the region. It had therefore occurred to him and to some of his colleagues in the Geological Survey, after studying those great problems on the spot, that experiments might be made to throw light on the Survey work in the N.W. Highlands, by seeking to imitate in the laboratory the processes they believed to have been in operation at an early geological period. He had therefore begun a series of experiments based on such lines, which had been attended with great success, the resulting structures having a marked resemblance to those observed in the field.

With the aid of numerous diagrams, sections of strata, and geological maps, Mr. Cadell brought before the meeting the results of a number of the experiments he had previously made, and by the use of coloured sands and other materials he showed the remarkable results of pressure applied laterally to horizontal strata, which bore out to a wonderful degree his former theories on the subject.

Remarks on various points touched on in the course of the paper were made by the Chairman (Mr. Bell), who said that some of the remarkable structures he had met with on a visit to Switzerland last summer were distinctly explainable on the lines of Mr. Cadell's experiments, which were also, by Mr. John Young, F.G.S., pronounced to be admirable. Mr. William Jolly, F.G.S., stated that the problem of the N.W. Highland rocks, supposed to have been solved many years ago, had gradually become chaotic, but now its solution seemed to be proved with intellectual clearness. The lecturer of the evening had done more than any other man to render the subject of experimental geology comprehensive and conclusive.

SOCIETY'S ROOMS, 207 BATH STREET, 14TH MARCH, 1889.

Mr. JOSEPH SOMMERVILLE, *Vice-President*, in the Chair.

His Grace the DUKE of ARGYLL, K.C.B., was elected an Honorary Member. Mr. George M'Creath, mining engineer, 208 St. Vincent Street, and Mr. Robert Black, teacher, 18 Shaftesbury Terrace, were elected Ordinary Members.

Mr. W. J. MILLAR, C.E., made some remarks upon a locality of geological interest near Bowling, where he was at present constructing a reservoir for the Bowling Water Supply, and it was agreed that the members should make an excursion to it on Saturday, 23rd March. [For notes on the locality see page 203.]

The recent death of Mr. Matthew Blair, F.G.S., of Paisley, a member of the Society, was feelingly referred to by Mr. John Young, F.G.S., who moved that a vote of condolence with Mr. Blair's widow and family should

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be passed. This was seconded by Mr. Dugald Bell and unanimously agreed to.

In a local paper an obituary notice stated that Mr. Blair was a successful man of business, and found in a moderate competence the reward of thrift, industry, and perseverance. But he was not altogether engrossed by the demands of his calling. He intelligently devoted a part of his time to scientific studies, and became known as a geologist of some standing. He was long a member of the Paisley Philosophical Institution, for some years convener of the geological section of that body, and at its last annual meeting was elected one of its vice-presidents. He was a member of the British Association for the Advancement of Science, the annual meeting of which he regularly attended; a member of the Geological Society of Glasgow, of which body he was for some time an office-bearer; and a Fellow of the Geological Society (of London). Some four years ago he formed one of the party of British Association members who went to the United States on a fraternal invitation from the *savants* of that country, and on his return he gave the members of the Paisley and Glasgow Societies some of the results of his experiences there. He was very familiar with the geological features of the neighbourhood of Paisley, and on various occasions he read descriptive geological papers to these bodies and contributed articles to the local newspapers. Mr. Blair took considerable interest in public matters, and in such improvements as the deepening of the Cart, of which he was an ardent advocate. He was long an office-bearer of the Abbey Close U.P. Church. He was a grandnephew of the poet Tannahill by the mother's side.

Mr. Robert Kidston, F.G.S., of Stirling, the well-known authority on Fossil Botany, read a paper "On the Fructification and Internal Structure of Carboniferous Ferns in their relation to those of existing Genera, with special reference to British Palæozoic Species." [See page 1.]

The paper was illustrated by a very large series of drawings and photographs, which were thrown on a screen by a limelight lantern.

At its close remarks were made by the Chairman (Mr. Sommerville), Mr. John Young, F.G.S., and by Mr. Thomas King. Mr. Kidston was afterwards proposed as a Corresponding Member.

Society's Rooms, 207 Bath Street, 14th April, 1889.

Mr. Daniel M'Millan, *Vice-President*, in the Chair.

Mr. Robert Kidston, F.G.S., Stirling, was elected a Corresponding Member.

Mr. John Young, F.G.S., and Mr. D. C. Glen, F.G.S., exhibited specimens and microscopic sections of a highly altered and decomposed White Dolerite intrusive in sandstone of millstone grit age, at Garngad, north-east of Glasgow. They explained the conditions under which the dolerite occurred in connection with the sandstone and a thin seam of impure coal, the dolerite being considered by the quarrymen a kind of pipe-clay. Along the line of contact both the sandstone and coal are seen to have been burnt and indurated by contact with the igneous rock; the

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latter, although now much decomposed, still showing distinctly, in thin sections, the highly crystalline structure which it originally possessed.

Mr. JOHN YOUNG, F.G.S., exhibited a small slab of Sandstone from Giffnock Flagstone Quarry, near Giffnock Station on the East Kilbride Railway, the surface of which, in the space of 9 square inches, showed distinctly some twenty pairs of vertical burrows of a soft-bodied marine worm. These burrows are now termed *Arenicolites* from their supposed resemblance to the burrows of the recent lobworm—*Arenicola* of the present seas. Mr. Young then referred to the seeming great abundance of the group of soft-bodied ringed worms in the earlier arenaceous strata of the various fossiliferous formations, in the seas of which they must have swarmed. He further pointed out that those which inhabited a single burrow in the sand were termed *Scolithus* and *Scolecoderma*, and those which inhabited double burrows, like those exhibited, were named *Arenicolites*.

Mr. ROBERT DUNLOP exhibited specimens of Mineral Paraffin from Airdrie, where it is rare. It appears to be a product of distillation from oil-bearing strata at a time when they were exposed to considerable heat, probably from intrusive igneous rocks. Mr. Dunlop stated that a miner's opinion of it was pithily expressed when he said he thought it was "some of the creesh left about the time of the Flood." Specimens of the same mineral from Linlithgowshire were exhibited by Mr. Joseph Sommerville, *V.P.*

Mr. JOHN HOWAT exhibited two fine examples of Hematite from Cumberland—one of them mixed with crystallised barytes.

Mr. J. B. MURDOCH, *Honorary Secretary*, exhibited a portrait of the young Norwegian explorer, Dr. Frithjof Nansen, who, with five companions, had, last autumn, achieved the arduous task of crossing Greenland, and read some interesting details of their adventurous journey. He remarked that as Greenland was still in the grasp of a great ice-sheet, presumably somewhat similar to those which at one time or another had dominated our own country, Dr. Nansen's observations would be awaited by geologists with the keenest interest. From the fact that the party had been unable to reach the last steamer for the season, and had therefore been forced to winter in the island, only meagre details had yet reached us. He hoped on some future occasion to return to the subject.

Mr. MURDOCH then read some interesting notes (on behalf of Mr. W. J. Millar, C.E.) on the geological features observed in the excavations required for the new Bowling Water Works, and as seen by the members who visited the spot on 23rd March. When the Boulder-clay was removed, splendidly glaciated rock-surfaces were exposed, and the striæ showed that the moving ice had been forced straight up against the rock, which was lying at an angle of not less than 50 degrees. [See page 203.]

SOCIETY'S ROOMS, 207 BATH STREET, 9TH MAY, 1889.

Mr. DANIEL M'MILLAN, *Vice-President*, in the Chair.

Mr. WILLIAM DOUGLAS, quarrymaster, Golconda, Kilwinning, was elected an Ordinary Member.

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Mr. DUGALD BELL, *Vice-President*, read a paper entitled "The Phenomena of the Glacial Epoch: II. The Great Submergence." [See page 100.]

A discussion followed, and was taken part in by Messrs. John Young, F.G.S., William Jolly, F.G.S., H. M. Caddell, F.R.S.E., Steel, James Thomson, F.G.S., and the author.

SOCIETY'S ROOMS, 207 BATH STREET, 30TH MAY, 1889.

Mr. DUGALD BELL, *Vice-President*, in the Chair.

Mr. A. B. MOTHERWELL, Union Bank, Airdrie, was elected an Ordinary Member.

Mr. JOHN HOWAT exhibited a large series of beautifully drawn diagrams of Foraminifera from the Chalk of the North of Ireland, prepared by Mr. Joseph Wright, F.G.S., of Belfast, an ardent worker in the field of microscopic geology. Mr. John Young, F.G.S., and other members spoke of the great value of Mr. Wright's researches amongst these minute forms of fossil organisms, and referred to him as an example of how much good work might be compassed in his leisure hours by a man otherwise actively engaged in commercial pursuits.

Mr. D. C. GLEN, F.G.S., exhibited specimens comprising fine examples of (1) Geodes containing Crystals of Quartz and Calcite, from Iowa, U.S.; (2) Titanite or Sphene, from Renfrew, Ontario; (3) Specular Iron Ore, from Elba; (4) Geode of Chalcedony containing water, from Brazil; and made some explanatory remarks upon their occurrence and distribution.

Mr. JOHN YOUNG, F.G.S., read a paper "On a Peculiar Structure—Spines within Spines—in Carboniferous Species of the Productidæ." [See page 86.] In illustration of his paper the author exhibited under the Society's microscope several slides showing the arrangement of this hitherto unrecorded feature in the spines of this group of fossil Mollusca.

The CHAIRMAN briefly addressed the members on the close of the Session, during which some good work had been done, and hoped that they would all be spared in health and happiness to meet in the following October, bringing with them many objects of interest met with in their summer wanderings.

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PROCEEDINGS FOR SESSION 1889-90.

(32ND SESSION.)

SOCIETY'S ROOMS, 207 BATH STREET, 10TH OCTOBER, 1889.

Mr. DANIEL M'MILLAN, *Vice-President*, in the Chair.

The CHAIRMAN welcomed the Members and hoped that the Session just commenced might prove no way behind any of its predecessors in interest and value.

Mr. ROBERT WOODBURN GILLAN, Indian Civil Service, The Manse, Carmunnock, was elected an Ordinary Member.

Mr. JOHN YOUNG, F.G.S., exhibited a fine series of specimens of Polyzoa and Monticulipora, comprising over 20 species, discovered by himself this summer at Kirktonholm, East Kilbride, in Carboniferous limestone shale. He explained that most of the specimens exhibited were extracted from blocks of shale which had been partly burnt in the kilns. The shale in its natural condition is of a dark blackish grey colour, but it changes through burning to a rock of a yellowish grey, the fronds of the Polyzoa being a brownish black, and their lace-like structure contrasting more strongly with the colour of the stone than when found in unburnt shale.

Mr. JOSEPH SOMMERVILLE, *V.P.*, exhibited a fine Quartz Crystal, with a Cavity containing Fluid, from the Calciferous Sandstone of New York State, U.S. Such specimens are geologically of great interest. Remarks on the subject of fluids enclosed in mineral cavities were made by Messrs. John Young, F.G.S., James Thomson, F.G.S., R. Dunlop, and other members.

The HON. SECRETARY (Mr. James B. Murdoch), on behalf of Mr. James Bennie, of the Geological Survey of Scotland, read a paper entitled "On Things New and Old from the Ancient Lake of Cowdenglen, Renfrewshire." [See page 213.]

The paper was illustrated by a map of the district, and by numerous specimens of animal and vegetable remains, some of the more minute forms being shown under the Society's microscope.

At its close an animated discussion was taken part in by Messrs. Young, Thomson, D. Bell, James Anderson, and other members.

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SOCIETY'S ROOMS, 207 BATH STREET, 14TH NOVEMBER, 1889.

(ANNUAL GENERAL BUSINESS MEETING.)

Mr. JOSEPH SOMMERVILLE, *Vice-President*, in the Chair.

The HONORARY SECRETARY (Mr. Murdoch) read the Report of the Council for 1888-89. Mr. JOHN WIGHT, C.A., *Hon. Treasurer*, read the Financial Statement, and Mr. James WHITE, *Hon. Librarian*, submitted his Report on the Library. A cordial vote of thanks was thereupon unanimously passed to these gentlemen for their work on behalf of the Society. The following members were elected to fill the vacancies occurring in the Council at this time:—As Vice-President—Mr. John Young, F.G.S. As members of Council—Messrs. James Anderson, C. C. Bone, C.E., Daniel M'Millan, and David Ross, LL.D. Messrs. John Renwick and John Dougan were appointed Auditors for the current year.

Mr. JOHN HOWAT exhibited a number of specimens he had recently obtained from the Triassic beds at Forth River, Belfast, including Variegated Marls and Fibrous Gypsum, on which he made some remarks.

Mr. JAMES THOMSON, F.G.S., exhibited a specimen, lent by Mr. James Miller, Canning Street, Calton, of a Fossil Fish, *Glyptolepis septopterus*, Agassiz, in a fine state of preservation.

Mr. JOHN WIGHT, C.A., *Hon. Treasurer*, exhibited a specimen of Diatomaceous Earth from Skye, used commercially in the manufacture of dynamite.

Mr. JOHN YOUNG, F.G.S., exhibited a well-preserved cranial bone of a Carboniferous Labyrinthodont, which he had recently found imbedded in lower limestone shale at Braehead Quarry, near Busby. This bone, when compared with skulls of this group found elsewhere in the British coal-fields, seems to have formed one of the zygomatic or jugal bones of the skull of an amphibian reptile some 6 or 7 feet in length. The upper or exposed outer surface of the bone is ornamented with the same kind of grooved and pitted sculpturing as that seen on the skulls of the genus *Pteroplax*—one of the Carboniferous amphibians—teeth of which are recorded as having been found in this same locality. These lowly-organised amphibian reptiles are amongst the oldest of their class yet discovered, some five genera and seven species being noted from the Carboniferous strata of Western Scotland. They seem to have formed an intermediate link between the fishes and the true reptiles, having characters that are seen to be possessed by both of these groups. Their remains, which are very rare, are chiefly found in strata of freshwater or lacustrine origin, as they lived generally under aquatic conditions, and their footprints have occasionally been found impressed upon the muddy lake-shores of the period. The quarry at Busby in which this bone was found is the lowest geological horizon in which amphibian remains have yet been met with in the Glasgow coalfield.

Mr. JAMES THOMSON, F.G.S., also exhibited a specimen of a bone of the same reptilian character which he had found at the same quarry twenty-nine years previously.

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Mr. DUGALD BELL, *V.P.*, on behalf of Mr. John Smith, Kilwinning, read "Note on the Occurrence of Footprints in the Calciferous Sandstone between West Kilbride and Fairlie, Ayrshire." [See page 201.]

SOCIETY'S ROOMS, 207 BATH STREET, 12th DECEMBER, 1889.

Mr. DUGALD BELL, *Vice-President*, in the Chair.

Mr. William Ker, 1 Windsor Terrace, Kelvinside, was elected a Life Member. Messrs. Matthew Blair, Merchant, 1 Hampton Court Terrace, and William Ernest Parker, Master, Middle-class School, Barnstaple, were elected Ordinary Members.

Mr. D. C. GLEN, F.G.S., reported on the proposals made at the last meeting of the British Association in regard to Geological Photography.

Mr. JAMES S. M'LENNAN exhibited, from Cannibal Gorge, Reefton, New Zealand, specimens of "Petrified Moss" consisting of mineral deposits principally derived from heated waters strongly charged with lime and afterwards deposited on the vegetation which usually grew near hot springs; also specimens of Gold Quartz from the same neighbourhood. After some interesting remarks by Mr. M'Lennan, Messrs. John Young, F.G.S., Thomson, F.G.S., Glen, F.G.S., and other members spoke.

Mr. JOHN KIRSOP exhibited Sandstone containing dark patches, caused probably by the presence of metallic oxides, and showing curious concentric ring-like bands. The rock was said to be found *in situ* at Holywood, near Kirtlebridge, Dumfriesshire.

Mr. D. C. GLEN, F.G.S., exhibited a series of Crystals of Minerals he had recently obtained from Cumberland Lake district. Amongst others were fine examples of Baryta, or Heavy Spar, Arragonite, Calcite in twin crystals, and Quartz, some of the latter crystals being unusually perfect.

Mr. JAMES B. MURDOCH, *Hon. Secretary*, read the Journal of a Bore recently put down for water at the works of the Thornliebank Printing Co., Limited, and read some notes as to the correlation of the strata met with. [See page 207.] Some remarks on the subject were made by Mr. John Young, F.G.S., and other members, an opinion being expressed that the reason water had not been reached was probably owing to the presence of a fault cutting off the continuity of the strata dipping towards the bore. If its position could be ascertained greater success would likely attend the sinking of a bore on its other side.

SOCIETY'S ROOMS, 207 BATH STREET, 9th JANUARY, 1890.

Mr. JOHN YOUNG, F.G.S., *Vice-President*, in the Chair.

Mr. ROBERT DUNLOP exhibited Jaws, Teeth, and other remains of Ganoid Fish from the Carboniferous shales of the Airdrie district, including several undescribed and rare species. The Chairman and Mr. James Thomson, F.G.S., spoke of their occurrence.

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The CHAIRMAN (Mr. Young), on behalf of himself and Mr. D. C. Glen, F.G.S., made some further remarks upon the Tachylite rock found in the Old Quarry at Whiteinch in contact with the shales in which the fossil trees are there imbedded, and exhibited prepared sections under the Society's microscope. It was stated that since the period when their paper on this subject was communicated to the Society specimens of the various intrusive igneous rocks found in the quarry had been forwarded for examination to Mr. Frank Rutley, F.G.S., lecturer on mineralogy in the Royal School of Mines. The result of his microscopical examination and analysis has since been embodied in a paper read to the Geological Society, and printed in the *Quarterly Journal*, vol. xlv., 1889. The author there gives an interesting account of the minerals present in the different varieties of this rock, as also of the changes produced by the devitrification and weathering of the minerals themselves. It was pleasant to find that Mr. Rutley agreed with nearly all the statements made by Messrs. Young and Glen regarding the truly igneous character of the intrusive rocks found in Victoria Park Quarry. Mr. Dugald Bell, *V.P.*, Mr. James Thomson, F.G.S., Mr. Joseph Sommerville, and other members spoke upon the subject.

Mr. JAMES B. MURDOCH, *Hon. Secretary*, read, on behalf of Mr. John Smith, Kilwinning, a paper, on "The Great Ice Age in the Garnock Valley." [See page 151.] The paper was illustrated by a number of diagrams and sections. Remarks were afterwards made by Mr. Bell, Mr. Thomson, Mr. Murdoch, and other members.

SOCIETY'S ROOMS, 207 BATH STREET, 13th FEBRUARY, 1890.

Mr. DUGALD BELL, *Vice-President*, in the Chair.

Mr. ROBERT DUNLOP exhibited, for Mr. Robert Linton, Kilmaurs, a large slab containing Reptilian remains from the Annick Lodge shale beds, probably one of the Labyrinthodonts, *Anthracosaurus*, with a length of from 10 to 12 feet. The head has not as yet been found. Mr. Dunlop also showed, for Mr. Andrew Sinclair, Kilmaurs, Carboniferous Plant remains from the Kilmarnock coalfield, including *Lepidodendron serpentigerum*, said by Mr. Robert Kidston to be the first Scottish specimen yet identified, and examples of various other ferns in their young, and fruiting, stages. Remarks on these exhibits were made by the Chairman, Mr. James Thomson, F.G.S., and other members.

Mr. JAMES WHITE, *Hon. Librarian*, read a paper entitled "My Ideas of 'The Great Ice Age,'" in which he reviewed the whole subject of glacial action in its various aspects, strongly supporting the views expressed by Dr. James Croll, F.R.S.E., in his well-known work, "Climate and Time." The paper was illustrated by a number of diagrams and maps. At its close a short discussion took place, but owing to the lateness of the hour was adjourned to the next meeting.

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SOCIETY'S ROOMS, 207 BATH STREET, 13th MARCH, 1890.

Mr. JOSEPH SOMMERVILLE, *Vice-President*, in the Chair.

Mr. Robert Kidston, F.G.S., 24 Victoria Place, Stirling, was elected an Ordinary Member.

An adjourned discussion on Mr. White's paper on "The Great Ice Age," read at last meeting, was taken part in by Dr. Sloane, Messrs. James Thomson, F.G.S., James Miller, and other members.

The HON. SECRETARY (Mr. Murdoch) read, on behalf of Professor John Young, F.G.S., notes "On Mammalian Remains from Cresswell Crag Bone Caves," recently presented to the Hunterian Museum. [See page 210.]

The HON. SECRETARY also read, on behalf of Professor T. Rupert Jones, F.R.S., F.G.S., a paper, "On some *Estheriæ* and *Estheria*-like Shells from the Carboniferous Shales of Western Scotland." [See page 79.] At its close remarks were made by Mr. John Young, F.G.S., *V.P.*, who exhibited under the Society's microscope specimens of the fossils described in the paper.

SOCIETY'S ROOMS, 207 BATH STREET, 10th APRIL, 1890.

Mr. DUGALD BELL, *Vice-President*, in the Chair.

The HON. SECRETARY spoke of the excursions for the season, and remarked on a new feature on the card—a series of Friday evening excursions to easily accessible localities.

Mr. JOHN HOWAT exhibited a fine series of photographs of Rock Sections taken in the North of Ireland, and remarked that he hoped members of the Society would follow the good example set by the Belfast Naturalists' Field Club, and record photographically many of the fine geological sections to be found in the West of Scotland.

Mr. JOHN YOUNG, F.G.S., *V.P.*, exhibited a Carboniferous Fish, *Uronemus lobatus* (?), Agassiz, in cannel coal, from Loanhead, Fifeshire. The specimen measures 9 inches in length, but is imperfect at head and tail. Its most interesting character is the numerous series of long tubular or hollow ribs that extend downwards and outwards in a brush-like manner along the central line of the body where the vertebral column must have existed, though not here preserved. The ribs are of a dense bony structure, their hollow interiors being now filled with a white carbonate of iron and lime. The scales have been very thin, circular in form, and are of a brownish colour, having a minute microscopic ornamentation on their surface as in the Cœlacanthidæ, the group of fossil fishes to which this species belongs. *Uronemus lobatus*, with which Mr. Young was inclined to identify this specimen, was first described by Agassiz in 1843 from a specimen found in the Burdiehouse limestones. Since that time Dr. Traquair has described another larger species of *Uronemus* from the Upper Coal measures of Scotland, which he names *U. magnus*. It is also distinguished by its long dense rib bones and thin rounded scales. The specimen now

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exhibited was sent by Mr. Kinnaird of the Edinburgh Geological Society, and was the first example Mr. Young had seen of this species.

Mr. YOUNG also exhibited, under the Society's microscope, sections of a peculiar structure which he had recently discovered in specimens of *Fistulipora incrustans*, Phillips (*F. minor*, M'Coy). These sections showed the structure in a much finer state of preservation than those exhibited to the Society in 1883, when Mr. Young read some notes on this coral. Since that time he had always been on the outlook for specimens having the structure well preserved, only finding a few of the many he had prepared which well showed what he wanted. The structure seems to have been all very perishable, and to have disappeared in most instances either before or during fossilization of the coral. The specimens from Bowfield, Renfrewshire, were the only examples he had yet seen in which the spines were well-preserved within the walls of the corallites, but he had met with badly-preserved traces of their presence in one specimen from Roscobie, Fifeshire.

The perforated structure which Mr. Young discovered in the walls and sclerenchyma layers of the coral is fairly well-preserved in some of the examples found at Brockley, Lesmahagow, Trearne, and Dockra, Beith; but the finest example that has come into his hands was found amongst some fossils sent by Mr. James Bennie of the Geological Survey, obtained from shales on the banks of the Liddle Burn, Northumberland. In this case the coral was incrusting a stem of a crinoid. The section exhibited showed very distinctly the radiated structure of the walls of the corallites due to the slanting passage inwards of the pores or tubes that descended from the surface of the coral, where they appear as small acanthopores surrounding the corallites. These structures, which have not yet been figured in connection with this species of *Fistulipora*, have been examined with interest by Prof. Alleyne Nicholson, and now that it is known they do exist in all well-preserved examples of the coral it is hoped that a further look-out will be kept for them, and that they will be well illustrated and described in some future Monograph of the Carboniferous Corals.

The HON. SECRETARY (Mr. Murdoch) drew the attention of members to the recent discovery of coal-bearing strata near Dover as one of great geological interest, the existence of those rocks in that district having been many years ago confidently stated by some of the leading geologists of the day, although others, notably Sir Roderick Murchison, denied that there was any possibility of their occurrence.

The HON. SECRETARY then read, on behalf of Professor M. Forster-Heddle, F.R.S.E., St. Andrews, a paper, "On New Localities for Zeolites." [See page 72.]

SOCIETY'S ROOMS, 207 BATH STREET, 8th MAY, 1890.

Mr. JOSEPH SOMMERVILLE, *Vice-President*, in the Chair.

Mr. DUGALD BELL, *V.P.*, read a paper on "The Glacial Period: Recent Discussions and Progress," in the course of which he referred at some

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length to the Duke of Argyll's address to the Royal Scottish Geographical Society.

A discussion followed, being taken part in by the Chairman, Messrs. John Young, F.G.S., *V.P.*, James White, William Jolly, F.G.S., and other members.

SOCIETY'S ROOMS, 207 BATH STREET, 29th MAY, 1890.

Mr. JOHN YOUNG, F.G.S., *Vice-President*, in the Chair.

Messrs. John Chalmers, 14 Montgomerie Terrace, Mount Florida; T. Carter Parker, 3 Victoria Terrace, Dullatur; and Alexander Burrell, 227 West George Street, were elected Ordinary Members.

Mr. JOSEPH SOMMERVILLE, *V.P.*, exhibited a fine series of Graptolites from the Cambro-Silurian formation of the Levis beds at Quebec, Canada, and spoke of their occurrence and distribution. He also showed Plant Markings, and specimens of the rocks of the same district.

Mr. ROBERT DUNLOP exhibited Carboniferous Ferns from Ellismuir, near Baillieston, including *Lepidodendron Jaracyewskii* (new to Britain), *Neuropteris acuminata* (new to Scotland), *Odontopteris Britannica*, *Cyclotheca biseriata*, *Unatopteris tenella*, and the latter in fruit.

Mr. JAMES ANDERSON exhibited a number of fossils, including Fish Teeth —palatal, cutting, and petaloid, from the shales lying above the cement limestones of East Kilbride, which had been collected by Mr. Lindsay, successor to the late Mr. James Paton of that district.

The HON. SECRETARY (Mr. Murdoch) exhibited a collection of Plant remains—stems, rootlets, &c., which he had found in freshwater clay overlying the Arden limestone worked near Thornliebank, and which had been washed out for him by Mr. James Bennie of the Geological Survey.

The CHAIRMAN (Mr. Young) read a paper "On the Internal Structure of the Carboniferous Corals forming the Genus *Chætetes* of Fischer" [see page 57], illustrating it with a series of sections shown under the Society's microscope. Remarks on the subject were afterwards made by Mr. James Thomson, F.G.S., and other members.

The CHAIRMAN then declared the session closed.

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Geological Society of Glasgow.

INSTITUTED MAY, 1858.

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TRANSACTIONS

OF THE

GEOLOGICAL SOCIETY OF GLASGOW.

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VOL. IX.—PART II.

1890-91, 1891-92.

GLASGOW: PUBLISHED BY THE SOCIETY,
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The Editor begs to state that the Authors are alone responsible for the facts and opinions contained in their respective papers.

JAMES BARCLAY MURDOCH, F.R.Ph.S.E.

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TRANSACTIONS

OF THE

GEOLOGICAL SOCIETY OF GLASGOW.

No. XVII.—On Pectolite and Okenite from New Localities: the former with New Appearances. By Professor M. Forster-Heddle, M.D., F.R.S.E., &c.

[Read 12th May, 1892.]

Two years ago, along with Mr. Harvie-Brown of Dunipace, I lit upon a hitherto unnoted locality where the modifications of basaltic structure are more varied than perhaps at any other in Scotland.

Basalt as a rule does not yield many of the zeolites, and this locality is no exception to that rule. It ultimately proved, after a fair search, that but two occurred—stilbite and pectolite; and of the former only a single specimen, and that a poor one, was obtained. The pectolite was, however, in fair abundance.

Dr. Macculloch describes how upon his first being able to evade the shore breakers, and to land at one of the zeolitic localities on the south shore of Skye, he found loose-lying masses of zeolite which had been dislodged by the weathering of the cliffs, and had fallen to the beach—fair evidence, he conceived, to his having been the earliest gleaner at the spot. The same was our good fortune at the locality I allude to. This is that part of Torosay in Mull which forms the north-west portal of Loch Screden, and the precise spot is the shore opposite to the rock called the Derag Sgeir.

The shore cliff is basaltic for some little distance on either hand of this; and, loose perched upon the summits of some of the

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broken pillars, or lying amongst the comminuted and rounded fragments beneath, there were found several solid balls of zeolite.

These balls varied in size from less than that of a fist to more than that of a human head. When they departed in form from a nearly perfect sphere the departure exhibited a remarkable uniformity. This was the not unfrequent occurrence, especially in the larger balls, of a depression at one side, like that at the bottom of a bottle. The occurrence of several of these balls in position in the rock—some of a size greater than that of those found loose—showed that this depression was invariably at the base part of what had been a large steam vesicle ascending through a highly fluent magma.

The shape vouches in fact for an amount of fluidity greater than that which is disclosed by the form of the steam vesicles of the igneous rocks of Old Red Sandstone age in the Ochils; which vesicles have, in these rocks, by subsequent infiltration of silicious matters varying in colour and in substance, become agates.

These flows, as disclosed along a tract of country ranging from the Path of Struay to Partan Craig, had been so much more pasty than the basalt of Mull, that the steam vesicle assumed a balloon form, frequently with a sharp extremity, or even a silicified tag.

The white zeolitic balls collected from the Torosay shore proved of extreme toughness. While protruding portions could be broken with difficulty from the smaller masses by a swift blow of a light hammer, there was only one of the larger which could be fractured at the locality by repeated blows of a 12lb. hammer; and a mass little more than the size of two fists, when placed upon an anvil, only yielded to a 28lb. hammer after about thirty blows had been struck. The larger masses remain still unbroken.

This extreme toughness, and the structure disclosed upon the surface of fracture, left no doubt that the material was either pectolite or dysclasite (okenite), but the toughness was very much greater than that of any dysclasite which the writer had ever quarried.

The surfaces of fracture showed a multiplicity of mutually interfering, but hardly interlacing, groups of divergent crystals; these had a white or pale green colour.

This is so much the appearance of the pectolite of the West of Scotland,—whether found in veins in dykes, as at Manor House,

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Oban, or in druses, as at Talisker Bay, Skye,—that doubt as to the nature of the mineral would not have occurred, and an analysis would not have been considered necessary, but for two circumstances.

The first of these circumstances was the appearance presented by the mineral in a cavity in the one large mass which yielded to the hammer at Torosay. In this cavity the mineral was distinctly crystallized, but the habit of the crystals was entirely different from that of the flat, scaly, transparent forms which occur at Ratho, Kilsyth, Bougang, and elsewhere.

Here they were in acicular divergent and rosette groups, such as scolecite and mesolite assume. From the centre of the cavity a detached ball, studded on every side with such groupings, fell out. Unfortunately the terminations and surfaces of these crystals, which are one-half to five-eighths of an inch in length, are rough and opaque.

The second circumstance which led to an analysis being made was the unique appearance of one of the smaller balls which had yielded to the hammer. This was also, unfortunately, a unique specimen.

The appearance was so precisely that which might be expected in a massive gyrolite, or in a druse solidly filled with gyrolite, that I had no doubt as to being able to determine the optic properties of that mineral on micro-sections cut from the mass. Large foliæ of pearly lustre, and a distinct "sea-green" colour, passed from all sides to the centre; generally these foliæ were flat, but here and there twisted and interwoven.

The cutting up the specimen with the diamond wheel, however, disclosed such extreme toughness and hardness as to throw doubt upon the specimen being gyrolite—specimens of undoubted gyrolite from the Treshinish Islands having been found, when being slit, not to be characterized by a hardness greater than that of most zeolites.

The slices cut thus with extreme difficulty were placed successively in the hands of three of the best micro-section preparers in the country, all of whom, after several trials, failed in supplying me with the smallest mounted fragment. The slices during thinning either crumbled through continuous fissuring, or sprang from the glass.

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As a similar, and nearly as extreme difficulty, both as regards sectioning and thinning, is likewise experienced with pectolite, especially with what may be called *zeolitic* pectolite, it seemed to be possible that these substances might have some relationship to one another. This conjecture was fortified by the determination of their specific gravities, and by their blowpipe behaviour.

Supposed Pectolite.—Massive-fibrous, dull or glimmering. Gives strong sodium reaction. Fuses with difficulty to a white rough bead of glass containing small bubbles.

Sp. gr. on 327·4 grains, 2·763.
on 81·1 „ 2·742.
Hardness = 5.

Supposed Gyrolite.—Foliated, massive, pearly. Gives strong sodium reaction. Hence *not* gyrolite. Fuses to a glass clear while hot, becoming milky and enamel-like, but with bubbles, when cold.

Sp. gr. on 536·9 grains, 2·763.
on 66· „ 2·788.
Hardness = 5, or rather more.

This continued accordance rendered it necessary to analyse both; and Mr. Stuart Thomson, upon being applied to, very kindly agreed to associate himself with me in the enquiry, and undertook to make the analyses.

His determination of the specific gravity of the fibrous mineral was 2·736, which, with the foregoing, gives an average of 2·744; and of the foliated mineral 2·774, giving, with the previous determination, an average of 2·773.

The fibrous mineral yielded him as follows:—

Loss on drying, ...	·6
Silica, ...	53·74
Alumina, ...	·82
Lime, ...	31·19
Soda, ...	9·94
Potash, ...	none
Water, ...	3·38
	99·67

This is pectolite.

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Of the foliated gyrolite-like mineral three analyses were made—two by Mr. Thomson, and one by Mr. Carr Robinson.

Silica, ...	53·41	52·95	53·39
Alumina, ...	1·76	1·71	
Lime, ...	31·69	31·48	33·41
Soda, ...	8·11	8·04	8·80
Potash, ...	2·42	2·42	
Water, ...	3·66	4·07	4·46
	101·05	100·67	100·06

Two other determinations of the water gave Mr. Thomson 3·71 and 4·21 per cent.

Mr. Robertson, in the determination of the water, got no loss at 150° Fahr., at a low red heat 3·5 per cent., at blowpipe temperature 4·46 per cent.

This is *pectolite* also.

The analysis of the first variety shows us that pectolite crystallizes in *acicular* crystals as well as in crystals of the usual wollastonite proportions; the second analysis evidences the fact that substances of identical physical appearances may have an altogether different composition; *the identity of appearance of this variety of pectolite with gyrolite is absolute.*

There was an observation of very considerable interest made at this locality by the writer; the locality was visited in two summers, and during the last visit he carefully checked the observation made upon the first occasion, drawing the attention of his companions to the circumstances.

Four or five of the larger balls of pectolite were quarried out of the basaltic pillars, which have an average width of less than 2 feet. Most of these balls occurred altogether within the pillars, but two—one in each summer—were wrenched by chisel and pinch out of *two* pillars; that is, the ball formed a connecting link or "key" locking the two pillars together, and crossing as a solid mass without exhibiting any rent, depression, elevated ridge, or observable mark the small space, say, a quarter of an inch or less, which lay between the two pillars.

What does this teach, or *seem* to teach? These balls are the solid plugs of steam holes; steam vesicles which were slowly rising through a viscous and slowly solidifying mass. After its

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solidification they formed druses—tight cavities—which, upon the decomposition of the felspars, or of any nepheline which may have been in the rock, were, through the processes of endosmose and exosmose, filled, here solidly filled, with the zeolitic representatives of these altered components of the rock.

The "pillared state"—the rending of the flow into basaltic columns—must have taken place, not at the time of the solidification of the fluent or plastic mass, but after the endosmotic process had at least gone on to such an extent as to seal the cavity so perfectly that it had attained to the conditions necessary for the operation and continuance of the endosmotic process of transfer. Had the columnar rending taken place at the period of solidification, the rent which met the cavity would have permitted of the escape of the steam or gases, and the cavity would have been opened. It would indeed have been as open as the rents themselves—into which, as open spaces, no zeolitic matter passes, because there the conditions requisite for endosmotic action do not exist.

Seeing, however, that the rending, whenever it did take place, had neither opened the cavity, nor put an end to endosmotic plugging, it would appear that the rending had not taken place until the filling-up process was complete.

The above appears to the writer the only logical inference which can be drawn from the facts.

A corroborative, it may be said a fortifying, fact is the following. The writer has, in the northern wall-sided face of the most southerly of the islets of Inner Hyskier, seen a solid chalcedonic agate, of which one portion was in one of the pillars of pitchstone porphyry, while the other was in the opposite pillar.

The average dimensions of these pillars is about 8 inches in width. From one which was about 9 inches across the exposed face, he extracted the half of such an agate of zoned chalcedony, which was nearly 9 inches in length by 2 in thickness. The agate lay across the pillar with its rent surface on a level with the surface of the pillar. The shafted rock-face here plunges vertically into deep water: the rent agate was seen in passing in a boat.

Here it is evident that the contractile force of two pillars of 10 or 12 inches in width had been sufficient to cut by a clean rent,

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not merely the rock-substance itself, but also some 12 square inches of solid chalcedony.

The fact that the intervening rents of a basaltic arrangement carry no zeolites, while the pillars themselves may have many amygdules is in itself a significant one. It has been said that scolecite occurs between the pillars in the roof of the Cave of Staffa. It certainly does not occur elsewhere in the islet between the pillars at accessible spots, and it is not easy to see how the recorder of the above statement got to the roof of the water-floored chasm. With a great deal of difficulty, and a great deal of help, the writer got nearly half-way up the side, and the white substance which he saw was of a pendulous form, protruding downwards from the general level, and spreading like a smear laterally for some distance over the surface of the rent columns. Broken columns in the island sometimes show upon their rent extremities a film of rock milk. Probably the so-called scolecite is only a calcareous stalactite; calcareous infiltrations are to be seen, though very rarely, between basaltic pillars.

The above observations thus seem to indicate that the rending of a lava flow into basaltic pillars did not, in all cases at least, take place as the immediate result of a chill from surfaces of contact, and that they did not so result was a contention firmly held by the late eminent naturalist, Professor Fleming of Edinburgh.

Dr. Fleming even went so far as to maintain that the rending was a comparatively recent process, and so much of a surface action, that if a number of pillars were removed from the exposed face the structure would gradually disappear and every appearance of pillar arrangement cease to be perceptible.

As directly bearing upon such a question, it has to be remarked that it is by no means the invariable rule (though it certainly is the general one) that the skrinkage rents which form the pillars proceed from the two surfaces of contact.

The writer has seen a dyke in the cliffy bank of the south shore of Sorvaags' Fiord in Waagöe in Faröe where the pillars stand parallel to its sides, while at the top of the dyke they radiate like costæ of a clam shell.

In the Scuir of Eigg there are at several points within its mass clustered groups of divergent pillars, which groups impinge in all directions upon each other.

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Something of the same kind is seen in the semi-amorphous bed which overlies the colonnade at Staffa. And it is to be seen in a most marked manner in the vein of tachylite which cuts the basalt at the northern shore of the entrance of Loch Screden in Mull. Two localities can be mentioned by the writer where Dr. Fleming's contention seems to be borne out. The first is Balcarras Craig in Fifeshire, the second is a basalt dyke which crosses the Kinness Burn about a mile westward of St. Andrews. At both the process of quarrying is the removal of pillars—taking advantage in the quarrying of the absolute rock severance. At both the quarrying operations are abandoned intermittently on account of that rock severance gradually disappearing. At the Kinness quarry the severance more than once again became so evident and so open that the working was resumed. Doubtless this may to some extent be due to atmospheric agents developing and increasing the openness of a structure pre-existent though obscure; but it may also be due, at least to some extent, to a lateral relief of tension, and the actual recent establishment of rents.

Upon the writer's applying to Mr. Petheram, the road surveyor to the east of Fifeshire, that gentleman mentioned another locality where he had observed the same above-recorded facts—namely, the quarry at Faa Field, south of Drumcarrow Craig. He also stated that the quarry upon the south face of the Craig itself affords pillars for but a short distance inwards,—amorphous basalt, rent in every direction, succeeding.

The Ladeddie quarry, which is about 5 miles to the west of St. Andrews, may come to throw light upon this question. Magnificent clustered plumes of curved pillars are here seen. These lie in every direction; and so do not bear out any theory of contraction from cooling surfaces.

Such groups of pillars, when exposed in cross fracture during the quarrying operations, disclose rents of about an eighth of an inch between the columns. The dark-brown rock is seen to pass to pale green for a quarter of an inch round the margins of each pillar, and the intervening space contains transversely-fibrous pale green calcite. The dissolving of this by carbonated water leaves the pillars loose.

It is reasonable to expect that a rock pervaded by a system of

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rents which resulted from the contraction of a micro-crystalline mass, would in microscopic sections disclose some modified arrangement of structure at those parts which were in contiguity to the surface of the rents.

The number and the regularity of the cross-fractures* seen in basaltic pillars at some localities led to the view being sometimes held that a system of flattened spheres was therein manifest.

Had the rending been the outcome of contraction in the direction of a multiplicity of centres, it may well be supposed that a certain amount of difference in the crystalline arrangement of the constituent minerals would be observed not only in contiguity to the rents, but even passing inwards towards the centres.

The writer found upon the east coast of Morvern, in Argyllshire, at a point about half-way between Loch Corry and Glen Tarbert, a small basaltic dyke, which fell asunder into a number of fragments like compressed grape-shot. These, however, when sectioned, showed no perceptible difference of structure in any part.

It should here, however, be remarked that some varieties of spheroidal structure which, either from being disclosed through a more rapid weathering of the intermediate parts, or from a difference in colour, are quite manifest to the eye, disclose no structure when examined by the microscope. This holds for the spheroidal clay slate of the Shiant Islands, as well as for the dolerites of the same islands, and of Morvern.

The microscope thus throws no light apparently upon the question. The facts, however, observed in the above-noticed quarries, taken along with the observations at Hyskier, at least call for a reconsideration of the views entertained regarding the dominant cause of basaltic structure.

Okenite.

Pectolite does not occur, so far as known, in either Greenland, Iceland, or Faröe: the non-sodaic okenite seems to take its place. The appearance of the two minerals is much the same, as is also the habit of their occurrence. Icelandic specimens of okenite show no other mineral associate. The same holds for the specimens from Disco. In Faröe okenite was found by the writer in huge balls imbedded in the channel of a stream near Tiornevig in Stromöe,

* *I.e.*, fractures at right angles to the pillar-faces.

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and as a vein in Naalsöe at a point nearly opposite Torshaven. At both localities it was associated with no other zeolite.

Much the same thing is to be observed as regards the solitariness of habit of pectolite in Scotland. Though occasionally associated with other zeolites, such occurrences are very exceptional, and the quantity of these associates is small in relative amount. Very much the greatest quantity of the mineral occurs at Ratho, Lendalfoot, and Loch Screden; at the first of these localities it is almost always solitary, at the others invariably so. This statement as to absence of associates in the zeolitic druse applies only to the central portions or greater bulk of the cavity; for in many, if not in most cases of the occurrence of these minerals, a small amount of some other zeolite appears as a skin or first layer of deposition in the cavity. In the pectolite of the West of Scotland this layer is usually mesolite, rarely analcime; in druses filled with okenite it is usually heulandite.

Possibly the occurrence in Scotland of the sodaic variety of mineral may be explained by supposing it to be derived from labradorite (much the more common variety of plagioclase felspar in Scotland), and that okenite had resulted from the destruction of anorthite.

Still the evidence of the analyses subjoined goes to show, though not altogether satisfactorily, that okenite may occur in Scotland.

The first analysis was executed by Mr. Stuart Thomson, upon a specimen collected by the writer upon the south-west shore of Skye.

This shore is, except under the most exceptional circumstances, altogether unapproachable. With a south-west wind there lies no breakwater whatever between it and the Atlantic; with a south wind only the narrow width of Canna, distant 10 miles. The special danger of the coast is, however, due to the extraordinary distances to which great masses of rock have rebounded seawards in their fall from cliffs, which are at most points over 700, and in several attain to almost 1000 feet in height.

A maze of hidden danger has to be threaded; the altogether unexpected swell and break of a surf all around the boat has to be encountered; only upon two occasions has a landing been successfully accomplished at certain spots by the present writer. The almost immediate find of laumontite, altogether unrivalled, and of stilbite and heulandite, little inferior to that of Iceland, led him to

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conclude that a like success, as regards landing and remaining on shore, could not have been attained to for a very considerable period. It was indeed with longing eyes that he had upon one occasion to hurry to the boat, leaving undetached a specimen of analcime with a surface of about one square foot, which was covered with pale blue crystals, nearly all of 2 inches diameter.

The locality at which the finest heulandite was obtained lies intermediate between Lochs Einort and Brittle. It is a short distance north of the mouth of the Allt Leth-uilt. Poor specimens of stilbite, and one—that analysed—of doubtful okenite, were found.

This specimen was exposed in a rock-face as the half of a filled-up druse; the other portion could not be found.

It did not seem to have suffered from surface alteration, and was altogether similar to the Stromoë okenite, having a faint tint of greyish yellow. It was imbedded in a soft, loose-grained, wackenitic rock, which is likewise the matrix of the fine heulandites and laumontites found on this coast. The rock is very similar to that which carries heulandite at Berufiord in Iceland.

At a promontory half-a-mile to the south, Dunan Earr an Sguirr, a second small loose fragment of the same substance was found; this was more like the Disco variety.

Of the specific gravity of the first I made three determinations, and Mr. Stuart Thomson made another.

Sp. gr. on	109·8	grains	2·174
on	69·8	„	2·209
on	64·6	„	2·189
Stuart Thomson		„	2·219

Average, 2·198.

Hardness = 4·5. Of the specific gravity of the second I made one determination on 32·44 grains = 2·246.

	Mr. Thomson, obtained in the Allt Leth-uilt.	Dr. Heddle, Dunan Earr an Sguirr.
Silica,	48·28	54·22
Alumina,	4·14	·68
Lime,	30·63	27·22
Soda,	1·68	1·02
Water,	15·69	16·64
	100·42	99·78

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As the zeolites of the West of Scotland have very frequently a thin outer layer of what has not inaptly been called "basement mineral," which the writer has by analysis determined to be a scolecite with some soda,—the sides of the portions analysed, as also those taken for the determination of the specific gravity, were all removed by slitting. The results of the first, and indeed of both analyses depart considerably from the composition of okenite; still the accordance as regards specific gravity, hardness, and water content are so close that they cannot well be separated from it, nor is there any other zeolite with which they upon the whole better agree.

Sections of the two specimens showed that from the promontory to be the purer; there seemed to be a little scolecite at the edges of the other, some crystals of which might have penetrated its substance.

The micro structure of the mineral differs considerably from that of pectolite. Like many pectolites it consists of spherical groupings of radiating fibres; but these fibres are of markedly greater delicacy than those of pectolite, and the mineral polarises in very faint colours, whether in thick or thin sections.

Optic Properties.

Lacroix and others have shown that there is very great difficulty in discriminating between such zeolites as assume an acicular divergent structure; the following notes on the general, and on the optic properties of pectolite, okenite, and similar minerals can be regarded as no more than a contribution towards our knowledge. Such optic properties as are disclosed by the very unsatisfactory sections which (on account of the bitterness of these minerals) can alone be obtained, suffice, however, when taken along with their general structure, for their discrimination from each other in sections ordinarily obtainable; while they also suffice for the discrimination of the pectolite of Manor House from tesselated apophyllite, and of all the named minerals from stilbite.

Pectolite.—This occurs crystallized in Scotland at Ratho in Edinburghshire, at Kilsyth in Stirlingshire, and at Knockdolian in Ayrshire. All attempts which I have made to bring crystallized portions into a section have failed on account of this, that, however tough the fibrous portion may be, the crystals invariably break away.

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As a rule, pectolite is very difficult to work to a section—tending to split, and still more, to spring from the support. I have only succeeded in getting sections from Ratho; Gloom Quarry in the Ochils; Manor House, Oban; and Loch Screden in Mull.

The appearances seen in the Ratho mineral are typical of the others, with the exception of that from Oban. The characteristic feature is that, however thin the section, everything is seen as through a haze—colours and structural markings being alike dulled and blurred.

According to the angle at which the slitter has sectioned the fibres, the structure is lanceolate, or is engine-turned. Of the Ratho mineral the colours are dull green and red, with crossed Nicols; and the dark cross under crossed Nicols is very seldom seen on account of the large size of the divergent groupings. If the section is turned 45° the colours are yellow, purple, and orange. With the analyser set at an angle of 45° to the polariser, that which usually appears as a dark cross is still apparent, but it and the colours are alike pale.

Pectolite of Manor House, Oban. A thin vein in dolerite. Stuart Thomson found the amount of water in this to be 3·52 per cent. This shows a confused, matted, and divergent structure in its general mass. The colours, somewhat clearer than those of most pectolites, at vanishing thinness disappear, or pass to blue-grey or to darkness. Throughout this there lie, nearly parallel to the sides of the vein, comparatively large crystals, which, with crossed Nicols, obscure parallel to their length. With parallel Nicols they are colourless.

When turned 45° from the point of observation, with crossed Nicols, the crystals have an orange colour at vanishing thinness; and at the same point with parallel Nicols this changes to a brilliant blue and a deep blue.

Many of these larger crystals show a tesselated structure. This consists of a single line of rectangular tesselæ, which do not generally cross the whole width of the crystal. With crossed Nicols and the crystals set at 45° from the line of observation, these tesselæ are alternately orange and dark blue, becoming in the same position with parallel Nicols pale blue and lemon yellow respectively. They are thus altogether different from the tesselæ of apophyllite.

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With ordinary light the crystals are seen to be irregularly cross-barred by lines of dark dust. The tesselæ are sometimes defined by these lines, but are in no way dependent upon them—some barred crystals showing no tesselæ, and some without bars showing many, while bars cross the tesselæ themselves.

Wollastonite. Glen Urquhart.

Near the Free Church at Newton, Glen Urquhart, Inverness-shire, a vein of white fibrous wollastonite cuts a rock chiefly composed of hydrous anthophyllite, biotite, and diallage (?).

The writer determined its nature by analysis.

	1.	2.
Silica, ...	49·142	49·065
Alumina, ...	·617	·601
Ferric Oxide, ...	tr.	—
Lime, ...	43·7	43·01
Potash, ...	·634	1·008
Soda, ...	2·957	2·728
Water, ...	3·027	3·098
	100·077	99·510

Structure, massive-fibrous. Colour, skim-milk. Excessively tough. Sp. gr., 2·715. In appearance it is so like pectolite that its optic properties are inserted here.

It has a lozenge-like structure, delineated in pale brown tints. This is not due to the crossing of fibres from the opposite sides of the vein, as the acute angle of these lozenges is very much less acute than that of the diverging tufts of crystals, which indeed the lozenge structure crosses. Moreover, the structure is evident even up to the margin upon both sides.

Being an exfiltration vein, the crystalline tufts would grow from both sides. The more marginal portions having become solid structure before the fibres from the opposite side had reached the centre of the vein, these latter could not intersect them so as to form any such lozenge structure.

Xonaltite.—Geo da Tuill, Loch Einort, Skye; also Loch Brittle, Skye.

Shows both dark and pale blue, *under all treatment.* Had a very minute spicular structure.

Tobermorite.—Scuir nam Boc, Loch Einort, Skye.

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Has a large plumose structure: the tufts are quite independent of each other in their offsets, but are thereafter interwoven with each other. Very arborescent and branching. Blue and yellow colours appear together; these at vanishing thinness disappear, the section showing then only light and dark. The crystals seem to obscure parallel to their length.

Okenite.—Vein, Naalsöe, Faröe.

Obscures parallel to fibres. Blue and colourless seen together, very little yellow. Yellow dominant with parallel Nicols. The structure is very minute.

Tiornevig, Faröe. Solid druses.

Obscures parallel to fibres. Yellow to colourless with crossed Nicols. Blue passing to brown with parallel Nicols. At vanishing thinness with crossed Nicols is colourless to pale blue. Has a tufted structure, but not so much branched as tobermorite. Specimens from Bordöe, Faröe, are altogether similar.

Disco, Greenland.

More like the radiations of mesolite, but it could not be sufficiently thinned.

Loch Einort, Skye.

Is very similar to that of Naalsöe.

Loch Brittle, Skye.

Has finer fibres, and these radiate from a greater number of centres. This looks more like an intermediate with pectolite.

Mr. Stuart Thomson has sent me the results of an analysis which he made of specimens of the pectolite which I forwarded from Manor House, Oban.

Sp. gr., 2·734

Silica, ...	54·63
Alumina, ...	4·56
Lime, ...	26·68
Soda, ...	10·69
Potash, ...	tr.
Water, ...	3·92
	100·48

He remarks—"This high percentage of silica seems to be characteristic of the pectolites of the West of Scotland."

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No. XVIII.—The Late Sir A. C. Ramsay, F.G.S., Director-General of the Geological Survey of Great Britain. By John Young, M.D., F.G.S., &c., Professor of Natural History in the University of Glasgow.

[Read 14th January, 1892.]

The life of Sir Andrew Crombie Ramsay is of very special interest to Glasgow geologists. Born in our city seventy-seven years ago, he owed his start in the career which led him to fame to the share he took in the work of the meeting of the British Association in Glasgow in 1841. But the impulse toward science was of much earlier date. His father was associated with the chemical industry of Glasgow, not merely as a successful manufacturer, but as an inventor of processes which made the production of bichromate of potash and pyroligneous acid commercially remunerative. To home influences was added that of John Pringle Nichol, Professor of Astronomy in the University. Nichol was a man of remarkable power as well as genius. It has been said that genius means an infinite capacity of taking pains. Nichol's genius had little to justify that definition. He was essentially a poet, gifted with marvellous instinct for the meaning of scientific facts, and by virtue of his poetic gift capable of conveying to others in extraordinary fashion his sense of the inner meaning of what he had learned. Ramsay used his skill as a draughtsman in the illustration of Nichol's "Architecture of the Heavens"; and though in after years he had learned how unreliable Nichol was as a guide to facts, he ever owned with enthusiasm his great debt to one who had given him a love for science by showing him the grandeur of the generalisations to which its study might lead. It is, indeed, not too much to say that the West of Scotland is still under obligations to that forgotten genius, neglected because he was not always accurate, yet powerful, perhaps because he was not accurate, in rousing interest in science where there had been ignorance, enthusiasm where previous efforts had been laborious but narrow.

The Andersonian University Museum still contains the model of Arran which Ramsay prepared for the Association meeting of 1841, and it indeed deserves the name of a model. As a monument of its author's clear recognition of geological facts, of his capacity for inventing his own methods, of the intuition by which he arrived at

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the essential facts of geological surveying without teacher or guide or example, the model of Arran is, and will ever remain, a valued possession of the Technical College, and the copy in the halls of the Jermyn Street Museum will long keep green the memory of the self-taught geologist. For the work has to be measured, not by the knowledge of to-day, but by the ignorance of the time when it was done. Lyell's "Principles" began to be published in 1830; but the importance of what we now call historical geology had been tardily recognised, so tardily that the "Elements of Geology" was not published as a separate treatise till 1838. Prior to that time Scottish topographical geology had been largely mineralogical; and it is no small proof of Ramsay's power that his work on Arran was simultaneous with the publication of Maclaren's "Geology of Fife and the Lothians," a valuable memoir which owed much to the teaching of Jamieson and to the sympathetic rivalry among his disciples. These aids were not available to the Glasgow geologist, who had to teach himself the art of surveying and to discover the method of geological description. The apprenticeship thus served was laborious, but its fruits have been of the highest value to British science, for no school could so well have prepared for his duties the future head of the Geological Survey. Yet that position was only accidentally rendered possible. Murchison had been greatly impressed by the work of Ramsay, and invited him to share an American tour which he had contemplated. But the Russian expedition with von Keyserling and De Koninck had superior attractions, and Murchison, who had, before his change of plans, taken Ramsay up to London, secured his engagement under Sir Henry De la Beche, who had already begun the Local Survey, which he dexterously converted, almost without the knowledge of the ministers whom he made his associates, into a National Survey. Ramsay joined Sir Henry at Tenby, and the association was a most fortunate one. De la Beche has scarcely had justice done him. The pedantry of the Prince Consort could only see narrow-mindedness and the domination of one idea in the tacit opposition De la Beche showed to "the milky mixture of science and art" which now wastes so much of the money and time of the country in teaching which is not education and manipulation uninspired by art. De la Beche had far wider views than those patronised by the Prince and obediently applauded by

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some who have since grown to honour thereby. A man of wide culture and of great artistic taste, accurate beyond the wildest dreams of contemporary geology, bold yet cautious in reasoning, and endowed with that great literary gift which makes simple unadorned English interesting and even eloquent, he found in Ramsay an apt pupil and a congenial associate. Descriptive geology was the aim of Sir Henry. He had to earn an extension of his scheme by proving its economic value; and thus the philosophic study of geological processes received only as much attention as could be spared from due attention to mining industries. Those who have read De la Beche's "Geological Observer," especially if they have read it early in life, will bear witness to its fascination. One feels that he is reading, not a scientific treatise, but his own views and observations; and the everyday character of the studies detailed is enhanced by the pictorial illustrations which Sir Henry's fine taste substituted for the crude diagrams of his predecessors and contemporaries.

Under such a chief the best qualities of his subordinates were elicited. When Ramsay joined he found himself in a brilliant company of young men, who afterwards earned distinction—John Phillips, Captain James, David Williams, Warrington Smythe, and later Edward Forbes, Oldham, Jukes—all men of ability, culture, scientific enthusiasm, and genial character. It is difficult to fancy a more fascinating life than that of the early surveyors. Field-work at that time in the lovely scenery of South-West England—field-work during the day, in the evening comparison of notes, discussion of views, and lively talk, made life seem one long holiday. How much more must it have so seemed to a Glasgow man who had plenty earnestness at home, but who not merely found, to his surprise, that earnestness and fun were compatible, but discovered that the best work owed something to the combination. In 1846 appeared his memoir on "The Denudation of South Wales and the adjacent Counties of England," a memoir which proved the capacity of its author as a careful observer, and still more his power as a thinker, whose boldest influences were ever found to rest on a solid foundation of demonstrated fact. The treatise was curiously modelled on the style of his loved chief, whose memory, carelessly held by his country, lives best in the history of British science as

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the founder of field geology. It was perhaps a misfortune in the long run that the Geological was so closely linked with the Ordnance Survey. Yet it had its advantages in the accurate mapping which had become habitual before the two departments were finally severed. Few, nowadays, have any conception of the hindrances in the way of field geology nearly fifty years ago. The difficulties of transport were considerable; there was not even the cultivated slowness of a Cambrian railway; accommodation was of the simplest, and not always to be had; while maps were by no means at command nor of the scale which facilitated work. To this last circumstance is perhaps due the copiousness of the notes necessary to explain the brief signs on the maps, the detailed records thus compelled becoming a valuable tradition in the Survey. Meanwhile the service assumed greater importance, and with it greater dimensions. Ramsay was in 1845 appointed Local Director for Great Britain, Captain James for Ireland, Sir Henry being Director-General. In 1848 he was appointed Professor of Geology in University College, and marked his entrance on the duties of a teacher by a masterly history of geology. In later years he was wont to impress on his staff the duty of keeping clear in their minds the work done by earlier writers; he rightly maintained that this was an obligation of gratitude which would be rewarded by the mental training it involved. In obedience to his principle, he examined the systems of earlier writers, and his comments are remarkable for a man of thirty-four who had spent so many years in business and later in field-work. The thinker and the observer were rarely combined. To the early Survey days belongs the remarkable anticipation of much later work in the reference of the Old Red conglomerates to ice-action. No doubt it has been overdone by other writers, and the facts, which are few, have been tortured into proofs of recurrent glacial epochs, a kind of speculation which Ramsay certainly would not have encouraged. Ice had an attraction for him; he spent time in the Swiss Alps; he visited America in 1857, and afterwards wrote on the Glacial Phenomena of North America, which he had examined in the company of his old colleague, Sir W. Logan, and of Professor James Hall. "Peaks, Passes, and Glaciers" contained a paper by him which was afterwards published separately under the title, "Old Glaciers of Switzerland and North Wales." This volume is

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still of great value, for it did what Ramsay thought should be done for all formations, it endeavoured to restore the scenery and geography of the past. The pencil which illustrated the "Geology of Arran" with picturesque vignettes was utilised in the portraiture of Welsh scenery as it is, and the restoration of the glacial conditions. The curious reader will find, incidentally mentioned, ideas which afterwards were the means of earning credit to later writers. The radiation of ice from hill regions, and the re-arrangement of the drift on the lower grounds during emergence, he was content to note. But the excavation of hollows by ice he afterwards elaborated, and though opposition of all sorts has been active, his theory of the ice-wearing of lake basins solves a very large number of cases better than any other that has yet been brought forward. It is interesting to note that he did not at first appreciate the source of the difficulty felt by many of his critics, for his long familiarity with section-drawing made him forget that others were not so familiar and could not picture to themselves features on true scale. Huxley did him service by pointing this out. It was part of the Local Director's duty not merely to edit "memoirs," but also to superintend the execution of maps and sections. To this practice, following, as it did, on field-work, we owe the Plain of Marine Denudation first sketched by him in 1847, but later (1862) almost independently recognised and elaborated by Jukes in his classical paper on the river valleys of South Ireland which has so simplified our views on denudation. It was a very simple thing when explained, yet it represents a series of very fine generalisations and a strong grasp of geological processes. The solution of the difficult question, how rivers cut across mountain chains, was at once accepted as self-demonstrated, and its further application in later years to the valley of the Moselle received criticism mainly in details.

Those associated with Ramsay in the Survey work had often occasion to recognise the careless lavishness with which he threw out the generalisations dictated by years of observation and thought, generalisations worthy of detailed elaboration. A passing comment on a paper before the Geological Society sometimes summed up a long study, and by its announcement rendered further talk needless. The caution to students of glacial phenomena lest they should make too much of an episode

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was wasted, for those under the domination of that *idée fixe*, that amiable monomania, had not realised the Glacial Epoch as of less importance than the Cambrian. I am aware that glacialists (they have selected that title for themselves) have small respect for the caution which is now amply justified; but it was Ramsay who recognised the value of Croll's hypothesis and introduced it to the notice of geologists (*Reader*, 1865). Early acquaintance with astronomical work doubtless made his interest in the hypothesis readier, but it is not of less merit that a man devoted to the practical study of a science was open-minded enough to accept as worthy of study an hypothesis which went beyond the facts of his environment and reduced to a minimum the influence of physical geography. Another generalisation has lain dormant far beyond the time within which it ought to have been re-discovered and promulgated as new. It was, for the time, a daring thing to speak of the Carboniferous limestone as an episode in the Later Paleozoic Period. It was uttered while the nomenclature of cataclysm was dominant, while Sir R. I. Murchison ruled, and, as ruler, adopted language implying the succession where now we recognise the overlapping of epochs. Murchison spoke of time-periods where we now recognise geographical areas. To Ramsay, the pioneer of the latter view, the Paleozoic Epoch was a succession of geographical pictures, and in one of these he saw the Carboniferous limestone sea, a Mediterranean in the Devono-Carboniferous land. I have attempted, in a notice in the *Philosophical Magazine*, 1888, to realise Ramsay's view by tabulating the land and marine areas so as to show what he meant by episodes.

The generalisation of the Red-coloured strata as indicative of lacustrine conditions was a remarkable one. No chemical investigation had then supported his contention, which rested merely on observation. The paucity of fossils, on which he largely rested his theory, would now be regarded as a slender basis, yet no subsequent enquiries have invalidated an opinion which was to some extent the product of intuitive perception of the relations of strata.

The publication of the "Physical Geology and Geography of Great Britain" marked an epoch in popular geology. Without pretensions to literary distinction, the plain narrative of a man

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who was conversant with every detail, the book passed into a fifth re-written edition; its popularity was conquered by its directness. Ramsay had abundant critics, who declared that he did not respect the dignity of science. They are forgotten, because they mistook intumescence for dignity, rigid technicality for clearness. No one who heard Ramsay address the Royal Institution would fail to understand the secret of his success as a lecturer. Familiarity with the best English writers, perfect mastery of his subject, and thorough sympathy with the imperfect knowledge of his audience, gave him a grip which more pretentious speakers never acquired. He was a most methodical speaker, his lecture was planned out carefully by time, his subjects had each the number of minutes allotted, so that he never gave undue proportion to any section of his address. As a consequence he had never to change the plan of his lecture during delivery, for his auditors never tired of one topic before he had passed to the next; the whole was a continuous series of independent statements, reaching its climax when with the spark of his own intense conviction he welded them all into one harmonious unassailable conclusion. His personality counted for a good deal. A handsome presence, a native refinement which varied intercourse with all classes had converted into a courtly address, a fine sense of humour, and a curiously weak sense of his own power, all these enlisted his hearers in his behalf, and had he been far less accurate, far less earnest, would still have won their sympathy.

The work of Ramsay's life, the *magnum opus* on which his fame will rest, is the "Geology of Wales." It is a monument of solid work such as few men can look back upon. Only those who have attempted the study of Welsh stratigraphy can realise what that means. But the casual reader who has had no special interest in Wales will find in that classical memoir a vast amount of methodical research and careful inductive reasoning of infinite value in the investigation of other troubled regions.

But Ramsay's influence was perhaps even greater and more permanent as Director of the Survey. In this position he perhaps did not create (for De La Beche had begun the work) but he developed and maintained the English school of field geologists, which is characterised by accuracy of detail and systematic analysis of evidence. His inspection was very thorough, no point

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escaped his notice. He had not the rapidity of Murchison in seizing the main features of a country, but he did not so often err. Above all, he possessed in a high degree the philosophic spirit which enabled him to look at every investigation, however local, as a contribution to the principles of his science. The masterly use he made of the unconformities in the Welsh series makes his paper on Breaks in Succession a chapter in the geography of Silurian times, while the discussion of the red rocks similarly opened a new vista in historical geology.

Personally he was a most lovable man, a true gentleman in the highest sense of the term. Of spotless integrity, loyal to his friends, considerate to those who differed from him, he was loved by his associates; even his quick temper never for a moment marred the sympathy between him and his officers.

The ten years of his retirement have allowed him to fall out of men's knowledge, but they have also permitted a calmer survey of his relation to science than would be possible had he more recently dropped out of the ranks.

Since the days of Playfair no geologist has approached the position of Hutton's great interpreter. I still regret that the suggestion I made to Ramsay, that he should edit the "Illustrations," was made too late, or rather that his health gave way so soon thereafter. His ripe experience, wide acquaintance with geologic phenomena and the relative literature, his open-mindedness and calm judgment would have entitled him to do for the science of the middle of the century what Playfair had done for that of his day. He has left no one behind him equal to the task.

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No. XIX.—The Geology of Kyle. By James S. M'Lennan.

[Read 11th December, 1890.]

The District.—The middle portion of Ayrshire "that bears the name of Auld King Kyle" is separated from Carrick on the south by the River Doon, and from Cunningham on the north by the River Irvine. It contains the district drained by the Ayr and its tributaries—the Lugar, the Coyle, the Greenock, and the Fail, along with the northern slope of the Doon valley, the country sloping to the south, watered by the Irvine and its affluents—the Burn Anne and the Cessnock, and some 15 miles of the upper portion of the Nith basin. It is divided from the shires of Lanark and Dumfries on the east by a ridge of hilly ground, rising in some places to elevations of more than 1000 feet. Its greatest extent from east to west is nearly 25 miles, and from north to south 24½ miles. It has a low and sandy coast-line of nearly 13 miles, on which are situated the thriving sea-ports of Irvine, Troon, and Ayr.

In treating of the geology of this district it will be needful to arrange and describe the various formations in consecutive order, beginning with the lowest—the Silurian.

There is found in the south of Scotland, stretching right across the country from St. Abb's Head on the east to the North Channel on the west, a broad strip of elevated land, including the Lammermoor and Lowther Hills, known as the Southern Highlands, composed of rocks belonging to the Silurian system. Strata forming the lower portion of this formation are found in South Ayrshire, including the valley of the Stinchar, and part of that of the Girvan. In the latter they are remarkable for the abundance and variety of their fossil remains, first made known to the world by Sir Roderick Murchison.

Lower Silurians.—The only rocks in Kyle of Lower Silurian age—belonging to the Llandeilo series—occur in the vicinity of Loch Doon, and in the district lying further to the east, bounded by the Water of Deuch. Here on the north these rocks are surrounded by a large fault which brings alongside of them lower Old Red Sandstone strata, and near Drockloch those of Carboniferous age.

These Llandeilo rocks are made up of beds of hard grey and blue greywacke with, sometimes, thin layers of dark blue and grey

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shales. In some places the greywacke becomes a conglomerate, enclosing rounded fragments of quartz, greywacke, and grit. Some 3 miles east of Dalmellington, a well-marked bed of this latter can be seen running along the side of Benbrack hill, containing pebbles as large as 4 feet in diameter. The officers of the Survey observed some faint worm-tracks in some of the shales in the vicinity of Loch Doon, the only evidences of organic life as yet discovered in the district. These Silurian rocks are also traversed by numerous veins or intrusive beds of pink felstone, which trend in a direction similar to the line of strike, viz., from south-west to north-east.

Upper Silurians.—In the valley of the Greenock Water rocks of Upper Silurian age (Ludlow and Wenlock) are met with. These form two long narrow areas stretching nearly parallel to each other—one to the north-west and the other to the south-east of the Ayr valley. They are a continuation of the rocks of the Lesmahagow district, and at Linn Burn and Lamon Burn, tributaries of the Greenock Water, contain many well-preserved fossil shells of several species. No crustaceans (*Pterygoti*) such as are found in all parts of the Logan Water district have been as yet discovered in the Muirkirk area.

Old Red Sandstone.—Between the Silurians and the lowest member of the Carboniferous system in Ayrshire there is found a great series of sandstones, flagstones, and conglomerates, with masses of interbedded rocks of igneous origin. These are regarded as belonging to the Old Red Sandstone, and have been divided by the Survey into lower and middle groups—the former running along the north-west side of the Silurian upland, while the latter lie unconformably on the first as well as on the Llandovery rocks of Upper Silurian age, and are covered in the same way by the lowest member of the Carboniferous series.

In the Dalmellington district the lower Old Red Sandstone consists of a narrow band of volcanic and aqueous rocks flanking the Silurian heights, and bounded on all sides by faults. The one running north-east and south-west divides it from the elevated region to the south, while those on the north and north-west bring it alongside of the Coal measures and Carboniferous limestone, and, south of the Doon, beside Silurian rocks of Caradoc age. The Old Red Sandstones consist of conglomerates, shales, and hardened

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mudstones, with their intrusive felstones and mica traps. The conglomerates contain fragments of grit, felspathic sandstone, and quartz, all well rounded. The aqueous rocks are shales and sandstones, jointed and shattered, and sometimes much hardened in texture. The igneous rocks associated with, and of the same age as, these are made up of various porphyrites of either a dark purplish colour, dull, fine-grained, and amygdaloidal, or a lightish blue colour, less earthy and more crystalline in texture.

In the neighbourhood of Sorn this sandstone forms the well-marked hill of Blacksidend, rising to the height of 951 feet. Here, and also in the district of Lanfine moor, it is much flanked by faults which bring alongside of it rocks of Carboniferous age. Its strata consist of three different sets of rocks—(1) an upper set of volcanic beds, with conglomerates and ash-like sandstones; (2) a series of red and grey sandstones; (3) a lower group of rocks which have been very much altered. The quarries at Penning Hill, Changue Burn, belonging to the second set of this series, have yielded a characteristic fossil of the lower Old Red Sandstone—*Cephalaspis Lyelli.* The upper or volcanic series, so well developed in the Burn Anne near Galston, has long been famous for its pebbles. "These are usually turned up by the plough in the loose trappean soil, and have, doubtless, been derived from amygdaloidal and irregular cavities in the rotten and rapidly weathering trap rock."

The only place in Kyle where rocks placed by the Survey in the middle division of the Old Red Sandstone are found, is a little to the west of the village of Dalrymple, where they form a narrow strip on the northern slope of the Doon. This tract forms a part of the north-eastern margin of the district nearly comprising the angle formed by the Girvan and the Doon, and stretching along the coast from the Heads of Ayr to the mouth of the Girvan Water. Its rocks consist of reddish and greenish sandstones and conglomerates overlying the Silurians, a group of porphyrites of great thickness, a series of sandstones of various colours, beds of porphyrites, tuff, sandstones, and conglomerates, and, as their upper member, reddish micaceous sandstones, which, at the Heads of Ayr, contain specimens of the *Pterichthys major.*

The second group in upward succession, which consists of porphyrites, is locally developed to a great thickness, and forms

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the heights between Maybole and Dailly, culminating a short distance north-west of the Doon in Carrick Brown Hill at an elevation of 940 feet. These form the best development of the middle Old Red Sandstone to be found in the county of Ayr.

Carboniferous Rocks.—The Carboniferous system covers a much larger area in Kyle than any or all of the other formations put together, and consists of the following groups in ascending order: —The Calciferous sandstone series, the Carboniferous limestone series, in some places the Millstone Grit, and the true Coal measures. The region it overlies may be divided into the following coalfields, which will be successively referred to—the Kilmarnock and Galston, the Ayr and Coylton, the Dalmellington, the Cumnock, Lugar and Sorn, the New Cumnock, and the Muirkirk coalfields.

In the Kilmarnock and Galston field, which extends from the river Irvine on the north to the Dundonald and Craigie Hills, to the Permian rocks near Mauchline on the west and south, and to the Old Red Sandstone of Auchmannoch on the east, the Calciferous sandstone is well developed, especially in the course of the Cessnock Water, from Auchmannoch Moor to Black Briggs, and from Craighead to Haining Mains. In this last locality the stream has cut a deep gorge, known as Craig Connor, bringing to view both members of the series. Good exposures of it can also be seen in Killoch Burn, Auchmillan Burn, and Burn Anne, as well as in the small streams flowing from the north-east side of the Craigie Hills. The series consists of a lower group of reddish coarse-grained sandstone with, here and there, bands of a concretionary coarse sandy limestone, known as cornstone. Remains of plants are met with in these sandstones, but are neither many in number nor well preserved. Over these occur a series of impure ferruginous limestones (cement-stones) and green, grey, and reddish shales, with beds of sandstone. The former contain *Entomostraca*, and the latter abound in some places with these and other organic remains, along with worm-tracks, ripple-marks, rain-pits, and sun-cracks.

The Carboniferous limestone series consists of a suite of sandstones, shales, and limestones, with seams of coals and ironstone.

Along the sides of the Craigie hills the cement-stone group of the Calciferous sandstone is overlaid by a bed of limestone, which, by numerous quarries, can be traced for a distance of more than 3 miles, from Inchgotrick farm to Cessnock Water at Dalla Hill.

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This is supposed to be the lowest Howrat or Beith limestone of the Dalry basin, and at Howcommon consists of "black shale and ironstone, blue limestone about 4 feet, blue shales 3 feet, and a layer of white limestone 4 feet in thickness, resting on blue shales." The Survey gives a list of ten different fossil genera found in this bed. A mile west of Harelaw, in the same district, a second or upper band has been quarried, and it is thought to have its outcrop at Colliebarlees, a short distance to the east of Craigie village. In the course of the Burn Anne the lowest limestone is not so well developed as at Craigie, and the same diminished appearance obtains in its exposures at Killoch Burn, Wheitshaw Muir, and Auchmillan. In the second of these localities attempts have been made to work the thin coals associated with the limestones.

The Coal measures in the Kilmarnock and Galston district, like the other coalfields in Scotland, consist of an upper group of red and purple sandstones and clays without any coal seams, and the true Coal measures, made up of grey, white, and yellow sandstones, dark shales, fire-clays, coal seams, and ironstones. There are five workable seams in this locality —

M'Naught coal,	2 ft.	6 in.	to	3 ft.	6 in.
Tourhall coal,	2 „	0 „		6 „	0 „
Major coal,	4 „	0 „		7 „	0 „
Stone coal,	4 „	0 „		5 „	8 „
Main coal,	7 „	6 „		11 „	0 „

The Stone coal forms what is known as the "blind" coal of Caprington, which is thought to have become "blind" or anthracitic from the presence of an intrusive mass of igneous rock in its neighbourhood. The Main coal of Hurlford as it goes westwards gets split up into three separate seams, which are known as the Splint, Turf, and Wee seams; and though there are some 60 fathoms of strata between it and the limestone series these contain no seams that at present can be worked with profit, whereas in the Kilwinning field some good seams occur in these equivalents. A little distance south of the Permian rocks of Mauchline and Tarbolton a narrow strip of the Coal measures is met with, and at Rouchdike and Adamton coal has been worked. In the latter place it consists of two seams, one a gas coal, and the other a household coal 3½ feet thick.

The district extending from the mouth of the Doon on the south,

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and as far as Troon on the north, and inland to the foot of the Tarbolton hills by Stair and Drongan on to the south of the Craigs of Kyle (enclosing the coalfields of Ayr and Coylton), is bounded on its southern flank by rocks of the Calciferous sandstone group. The lower, or red sandstone series of this group is well seen along the course of the Doon from Cambusdoon to Auchindrane, and also above Dalrymple village. At Kerse Park, south of the Craigs of Kyle, these are found to contain remains of *Lepidodendron* and other coal plants. Its upper portion—the cement-stone group—can be seen well developed on the shore between Doon mouth and the Heads of Ayr, where some of its strata contain organic remains, such as cyprid cases, fish scales, and plants. Further inland there are few exposures of it to be met with owing to the depth of the drift, but some of its more calcareous beds, once burnt for lime—as evidenced by several old filled-up quarries and ruinous lime-kilns—testify to its presence.

The Carboniferous limestone series, which underlies the Coal measures, is not well represented. It can be observed a little to the south-west of the Craigs of Kyle at Bargenoch, but from that to the seashore no exposures of it are visible.

In this coal-field—the Ayr and Coylton—good natural sections of the various strata can be seen in the bed of the Coyle Water, as below the mansion-house of Sundrum the lower portions of the series are well exposed, and also between that and Garrochead the same stream flows over all the coals, and part of the overlying barren red sandstones. Sections of a like kind occur along the course of the Ayr, at Cameron's Holm and above Auchincruive.

The seams met with in this field are—

Ell coal, ...	3 ft. 4 in.
Craufordstone coal, ...	8 „ 0 „
Ayr Soft coal, ...	5 „ 0 „ to 7 ft.
„ Hard coal, ...	4 „ 0 „
Blackband ironstone, ..	1 „ 0 „

This ironstone is the same as the Burnfoot seam of Dalmellington, and has been found in bores to the south-west of Coylton village, but when worked there it was found to be unprofitable. The Ayr hard coal is the best in this district, and having been long wrought near that town is now exhausted. The upper barren sandstones, already referred to as well seen on the Coyle Water, are similarly

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exposed on the Ayr between Sorn and Ballochmyle, and also on the Burnock near Ochiltree. They "consist of red, reddish gray sandstones; red, purple, or lilac clays and shales, with sometimes a thin band of fine white limestone," and these clayey beds sometimes contain remains of coal plants.

In the Dalmellington field the limestone series has been worked at Patna, and here also is found its only workable seam of coal. In some of the pits it measures 14 feet in thickness, while in others it gets split up by intervening strata into two and sometimes into four seams.

The chief seams are known as—

The Craigmark blackband ironstone,		10 in.
„ Sillyhole coal, ...	5 ft.	6 in.
„ Chalmerston coal, ...	4 „	0 „
„ Minnivey coal, ...	3 „	6 „
„ Burnfoot blackband ironstone,	2 „	3 „

This last is the staple mineral of the district; at Waterside it has the above thickness, but thins out as it passes eastwards, till in the New Cumnock field it is only 2 inches thick. The Craigmark blackband, after being worked for some time, was found to turn into a gas coal as it passed eastward.

The Cumnock, Lugar, and Auchinleck field is merely an extension of the same strata as are found at Dalmellington. The limestone series is poorly developed, and its lower members occur at Laigh Holehouse and Blairmulloch, near Sorn. In the last-named place coal has been found, and at Laigh Broclar a gas coal has been worked. At Benston an upper seam of limestone has long been quarried.

The chief seams are—

Ell coal, ...	4 ft.	0 in.
Main coal, ...	4 „	0 „
Claud coal, ...	2 „	0 „
Maid coal, ...	4 „	0 „
Low Maid coal, ...	2 „	7 „
Blackband ironstone, ...	1 „	7 „

In the New Cumnock field the concretionary limestones of the Calciferous sandstone have long been worked at Gelt and Craigdullart, chiefly for agricultural purposes. Good sections of the whole series can be seen along the Gelt and Glenmore Waters.

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The limestone series is well developed, and consists of three groups—the lowest of which can be seen at Dalblair, and has been quarried at Dornal; and the upper one at Mansfield, Polquheys, and High Park. In the middle group are found the famous Edgehill coals, which form a little basin wherein the seams are very thick and close together, as is shown in the following section—

Gas coal, ...	1 ft. 8 in.
Strata, ...	10 „
Nine foot coal, ...	9 „
Strata, ...	16 „
Seven foot coal, ...	11 „
Strata, ...	12 „
Twelve foot coal, ...	12 „
Strata, ...	9 „
Three foot coal, ...	3 „

In 14 fathoms of strata there are 6 fathoms of coal, forming five seams. The strata between these seams are of varying thickness; a little to the east they disappear, and all the coals come together, forming a seam 40 feet thick. This lies in a little hollow known as "the ship."

The leading seams are known as—

Lane Mark gas coal, ...	5 ft. 4 in.
Boig or lower coal, ...	6 „ 0 „
Eight foot coal, ...	8 „ 0 „
Laird's coal, ...	3 „ 2 „
Creoch coal, ...	4 „ 1 „
Musselband, ...	3 „ 1 „
Position of blackband ironstone.	

This ironstone is here represented by an impure gas coal, or shale, used for making alum.

The Muirkirk coalfield is one of the richest and longest worked in Kyle. Here the limestone series is very well developed, having no less than ten seams of limestone. Of these, three have an average depth of 40 feet, and the other seven of nearly 3 feet, making a total thickness of 140 feet. They are highly fossiliferous, containing, according to the Survey, twenty-one genera and thirty-one species. This series also has nine seams of coal, four of which average 9 feet in thickness; six seams of clayband ironstone, with

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an average thickness of 11 inches; and one seam of blackband 10½ inches thick.

Overlying these is the Millstone Grit, made up of white and yellow sandstones and grits, with seams of fireclay and thin coal. It is also seen in the Lugar Water at Wallaceton, but is much thinner than at Muirkirk.

Its chief seams are the following:—

Claud coal, ...	3 ft. 3 in.
Maid coal, ...	7 „ 0 „
Low Maid coal, ...	3 „ 0 „
Musselband, ...	0 „ 6 „
Five foot coal, ...	5 „ 6 „
Six foot coal, ...	6 „ 6 „
Blackband ironstone, ...	1 „ 0 „
Three other coals (average), ...	3 „ 3 „

The blackband has been the chief object of search, and is the same as that worked at Lugar and Dalmellington.

"The clayband ironstones of this district were formerly largely sought for, and, when smelted by the cold blast process, made exceptionally good iron, which was then noted in the trade for its excellence; but since the discovery of blackband ironstones, and the invention of the hot blast, they have been allowed to remain unwrought. The ruins of the first blast furnaces erected in Scotland are still to be seen near Glenbuck, where these ores were formerly smelted."

Permian Rocks.—Lying in the middle of the coal-basin of Kyle is a large mass of igneous rocks and red sandstones of Permian age. These form an oval, having its greatest length from north-west to south-east, with its outside margin all round composed of porphyrites, melaphyres, and tuffs. Inside this, and overlying the above-mentioned rocks, is a set of brick-red sandstones, in colour and texture very unlike those of the Carboniferous formation. Good natural sections of these igneous rocks can be seen in the course of the Ayr near Ballochmyle and above Stair village. These are not the only evidences of volcanic action in Permian times met with in Kyle, for in many places the Coal measures are found pierced by masses of agglomerate, circular in form, which appear on the surface as small rounded hillocks. These "necks" were the vents through which volcanic material was ejected, and they

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are frequent in the Dalmellington coalfield. Good examples also occur at Raithill, near Coylton; Sorn Hill, near Catrine; in Ochiltree village; Little Hill, near Craigie; and a group of five are found to the south-east of Symington.

The red sandstone group is easily known by its brick-red colour. The River Ayr has cut it

> "Through many a wild romantic grove,
> Near many a hermit-fancied cove,"

into a series of deep and picturesque ravines, where the nature and composition of the strata are well displayed. Similar good exposures occur on the Lugar; and at Mauchline it has been and is extensively quarried for building purposes.

Post-Carboniferous Igneous Rocks.—These in the twofold forms of irregular sheets or bosses and dykes or veins are found bestudding the coalfields. In the Kilmarnock field the two largest bosses form the hills of Craigie and Dundonald, and smaller ones occur at Symington, Troon Point, and Holmes near Galston. Further to the north, in the Ayr field, they are met with at Auchincruive, Enterkine, and the Craigs of Kyle. At Stair "a thick series of pale-grey shales has apparently been hardened by the heated masses so as to form the well-known whetstones or Water of Ayr stones." These igneous rocks form, in the Dalmellington district, the hills of Benwhat, Ewehill, Benbeoch, Benbain, &c., and they also cover a considerable area in the neighbourhood of Aird's Moss, near New Cumnock.

The other form these rocks of supposed Miocene age assume is that of dykes, which are wall-like masses varying in thickness from a foot or two to twenty or thirty yards. "They descend to an unknown depth, and do not all reach the surface, and preserve their course with singular persistence, irrespective of the changes of dip and strike, or the varying nature of the rocks." Some of their courses can be traced for a considerable distance, as that which crosses the river Ayr at Auchincruive, and from thence runs in a south-west direction across the Ayr coalfield for more than 2 miles. The direction which in general these dykes are found to pursue is from north-west to south-east.

Boulder-clay.—The drift series overlies the most of Kyle, and underneath it, or where it has been removed, the hard rocks are

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found grooved and striated with the markings peculiar to the glacial period. In the south these striæ bear a north-west direction, turning more to the west as they leave the uplands and near the Clyde, while to the north their course is somewhat south-west, as is evidenced by the markings left on the hills stretching from Ardrossan to the confines of Renfrewshire. It would thus seem that central Ayrshire has been a meeting-place for the masses of ice that moved south from the Western Highlands, and north from the uplands of Galloway, Nithsdale, and Clydesdale. Blocks of metamorphic rocks are found in the Boulder-clay in the Irvine valley near Darvel, and in the valleys of the Lugar, the Glenmore, and the Gelt, and northwards to the slope of the Carrick Brown Hill range. Masses of grey granite from Kirkcudbrightshire are met with as far north as the heights of the lower Doon, and on the top of Genoch Hill, at an elevation of 1865 feet.

This deposit consists of two parts, an upper and a lower, the latter dark-grey or blue in colour over the Carboniferous areas, reddish over the Old Red Sandstones and porphyrites, and pale grey over the Silurians. It is hard and tough, and full of stones well rounded and striated, with here and there beds of sand, fine clay, and gravel. The upper is coarser, not so close in texture, and sometimes contains large blocks of stone more angular and less ice-worn than those found in the lower member. The group of sands and gravels overlying this clay is poorly developed in Kyle. About 1½ miles north-west of the village of Ochiltree some well-marked ridges or "kames" are found, and similar ones occur between Old and New Cumnock, and in a hollow between Benbrack and Clafin Hills near Dalmellington, 1000 feet above sea-level. The fine clay, devoid of stones, generally lying in hollows, a wash-out by rains and rills from the slopes of the Boulder-clays, has yielded specimens of Arctic shells. These were obtained from a bed of this clay cut open by the Pow Burn, a little to the east of Monkton, and comprised *Astarte compressa* and *Natica clausa*.

Raised Beaches.—There are found along the coast-line of Kyle remains of three different terraces at varying elevations, which evidence the varying sea-levels. One of these occurs between Monkton and Crosbie old church, at some 60 feet over mean tide-

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mark. A little to the east of Ayr racecourse there is the remnant of a second terrace, with the distinctly marked 40-feet beach constantly met with on the west coast of Scotland. The third terrace—the best defined and most continuous of the three—which has an average height of 25 feet and a varying breadth, stretches from the mouth of the Doon to that of the Irvine, and upon it all the coast towns of this district are situated. Its surface has been raised and roughened by the sand blown landwards from the existing sea-beach. Wherever vegetation has secured a hold the shapes of these mounds remain unchanged, otherwise their forms are modified by the action of every gale.

Alluvium.—In various parts of Kyle patches of alluvium are found. These are formed by the action of water laying down deposits of clay, sand, silt, loam, or gravel beside the courses of the streams. Sometimes these have been cut into several terraces by the stream flowing through the valley which they occupy, that of the present river being the lowest and most recent.

On the course of the Water of Ayr, from Stair to its mouth, good examples of these terraces are met with.

There are other patches, generally lying in hollows, which mark the sites of former lakes gradually silted up by the materials washed down into them, and by the decay of water plants, until at last they have become converted into meadows and cornfields. Some of the larger streams seem to have widened out into lake-like expansions, and these, partly by silting and by drainage (caused by the deepening of the river bed) have become fine alluvial land. Barleith Moss, a large hollow overlaid by alluvium, lying between the Irvine and the Cessnock, seems to have been formed in this way.

These ancient bogs or lakes are very frequent between Ayr and the Girvan valley, some now flat meadows or well-tilled fields, others marshes, or, where the inflow of sediment has been small, lakes with undiminished area. Several of these lochs in other parts of Kyle have been artificially drained, as that near Lochlee, which, at the time when Burns lived there (1777-84), covered some 20 acres, with double that extent in winter. A few years ago an interesting crannog or lake-dwelling was found within its area.

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Peat.—The hills in the south and east of Kyle have their flat tops covered with a thin coating of peat, but this deposit, formed of accumulations of decayed vegetable matter, is deepest and most extensive on the lower grounds. Much of the surface once overspread by it has been reclaimed and brought under cultivation. Considerable areas are still covered by peat to the east of Dalmellington, and Aird's Moss, lying between the Ayr and the Lugar, contains an extent of 3 square miles, with a depth in some places of 20 feet. Further to the north lies another large moss called Burnfoot Moor. Some 3 miles to the east of Irvine, Shewalton Moss covers an area of more than a square mile.

No. XX.—Scenes and Sections in Thornton Quarries, East Kilbride, in 1868. By James Bennie, H.M. Geological Survey of Scotland.

[Read 7th May, 1891.]

The exhibition of a portion of the cranium of a reptile, by Mr. John Young, from Braehead Quarry, at the Society's meeting in November, 1890, and the report of it which I had from the Hon. Secretary, Mr. Murdoch, which stated that Mr. James Thomson also exhibited a duplicate of the same fossil from the same place, awakened recollections of many visits which I made to Braehead and Thornton Quarries in 1868, during which I gathered innumerable fossils of certain kinds, and examined and measured in detail the sections exposed in the most typical of these quarries. Some account of this work may interest the members, and may assist any one who should think of further exploration in search of reptilian remains or other fossils from the same group of strata in that locality.

The origin of my visits in 1868 was this. As Mr. Thomson had expressed a doubt whether the coral named *Fungites* by David Ure was really found in East Kilbride, I offered to guide him to some quarries in that parish where I thought *Fungites* might yet be found. My offer was accepted, and one suitable day we went to verify it in South Shiels Quarry, which lay in the southern part of East Kilbride.

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Our way from Glasgow to South Shiels was by Carmunnock, Hairmyres, Newlands, and Crosshouse, partly by road and partly across country. After leaving Carmunnock the road passes through Brachead Quarries, and when we came to them, Mr. Thomson proposed a look in. I had some years before frequented them in search of fossils, and being interdicted therefrom, I had not visited them for some time; but now having a companion to champion me I thought I might break the taboo and dare the utmost rigour of trespass law. Accordingly Mr. Thomson leapt over the fence and I crept under it, and we passed along the shale heaps looking, like Autolycus, for any "unconsidered (geological) trifles" we could pick up. We had not gone very far when Mr. Thomson, who was in front, looted down, lifted something, gave it a look and shouted, "Man, I've got a big bone." After due inspection and admiration his prize was bagged, and our search continued. A little further on the same action was repeated and again came the shout, "Here's another bone," and truly another had been picked up lying loose, weathered out of the shale.

Thereafter we rambled over the other shale heaps and found several scales of *Rhizodus* and two or three small fish spines. We next entered upon the older workings on the east side of the road, finding a different shale in which coprolites were abundant, and soon we had our hands full of them. It is not necessary to recount further the day's proceedings, except simply to say that in Shiels Quarry Mr. Thomson found *Fungites*, and had his doubts as to whether Ure had really found it in East Kilbride completely dissipated. I may further say that henceforth the taboo was over for me, and that during the next three months I made frequent visits, twelve in all, to the Brachead and Thornton Quarries, ransacking every one, and every corner of each, and satisfying myself that little more was to be had.

The quarries were four in number, Brachead Old and New Quarries, and Thornton No 1 and No. 2 Quarries. Brachead Old Quarry consisted of a flat space formed by the tops of old shale heaps massed together, and a long sloping bank formed by the last couped shale. Over the flat space later outputs of shale had been tumbled down, and these often yielded good fossils, but the sloping face was necessarily the richest and most easily searched. Brachead New Quarry was then in active operation, with a large staff of

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workmen, and a large kiln constantly burning. The shale heaps in it were fresh and the shale was often in large slabs, the time since they were quarried not having been long enough for the weather to break them up and crumble them down. It was therefore most prolific in large bones such as Mr. Thomson had got, and arge *Rhizodus* scales.

At Thornton the quarries were also an old and a new one. The old one had been long standing still, and the large kiln was in a ruinous condition. But working in it had been lately resumed, ere my renewed acquaintance with it in 1868, and a railway led from it to a series of open kilns outside, so that the quarry was free from kiln reek. Thornton New Quarry was situated 200 or 300 yards further south, and, having been opened only a short time, everything was raw about it; but it had this advantage, that it gave an opportunity of getting certain shells, whole or nearly so, which in other quarries were only to be had in fragments on the over-weathered shale heaps.

Of the fossils found in the various shales it is not necessary for me to give a general list, as that has been already done, and well done, by Mr. James Neilson, in his paper on "Some Sections of Carboniferous Limestone near Busby" (*Transactions*, vol. iv., p. 282), so I shall only indicate the species I found on the shale-heaps, and then describe in detail the section exposed in Thornton Old, or No. 1, Quarry, which was by far the most typical of the four quarries that I have mentioned.

And first, the class of fossils that began to arrest my attention was that of the coprolites, which were literally in thousands, generally lying loose on the weathered shale-heaps. They varied greatly in size, from 3 or 4 inches in length to less than 1 inch, and in thickness from an inch to that of a stout quill. In form they also differed much, some being fusiform, others cylindrical or conical, or even nearly globular. It was easy to see in most of them which end had been protruded first—it being blunt, while the other tapered to a point. In many a scroll-like disposition was visible, most clearly seen in those broken across. The surfaces of many were wrinkled while others were quite smooth. Generally the matter they were composed of was fine-grained and compact, but a few had scales of ganoid fishes imbedded in them, and one was coated with such scales.

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Other fossils occurred, but not so frequently as the coprolites, still often enough to give a piquancy to the search, and to prevent it from becoming wearisome through monotony. The last of all were bones somewhat similar to those which Mr. Thomson hailed with a joyful shout, but not so big, and my eureka was whispered to myself; though sometimes when I found a large or extra good palatal tooth, for which I had then a passion, my exclamation was both loud and long. Occasionally conical teeth were got, which, from their appearance, I dreamed might be reptilian, as they differed from what I had been familiar with as fish, but of course I had to pass them with a point of interrogation attached to them in my mind. Encrinites were only represented in the upper shales above the main limestone by small ossicles in a thin band of green shale. Shells were chiefly confined, in the upper shale, to the bed above the limestone which Mr. Neilson has called the Hosie limestone. A few specimens of *Nucula* occurred in a perfect form, but small shells, which seemed to be *Spirifera Urei*, appeared in thousands. These were only in single valves and very friable, so they broke into dust as the shale weathered, and a passing glimpse was all I had of them. There was an entomostracan shale in which the shell-cases of these creatures were in thousands, but being in single valves they returned as dust to dust. Plant remains, in the form of roots, and more frequently rootlets, of *Stigmaria*, were seen permeating old soils now hardened into clay ironstone, and I have a record of finding a lepidodendroid cone and some twigs which showed signs of the internal structure being preserved.

In the course of gathering the fossils I soon found that certain forms characterised certain shales—that the coprolites, the fish scales and bones, the entomostracans, the marine shells and the encrinites, and finally the palatal teeth, occurred exclusively in shales that could be easily distinguished from one another. As the fossils differed essentially in character, some being marine, others lacustrine, while the plant roots and rootlets indicated unmistakably terrestrial conditions, it was manifest that, if a clue could be found, a succession of changes could be easily determined, and a history of the events that occurred in this corner of the Carboniferous world could be made out satisfactorily. Such a clue was instinctively sought in the section of strata exposed in the

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face of each quarry according to the established geological law that lower and upper meant before and after. The intimate acquaintance I had made with the fossils and the different shales in which they were found enabled me to recognise readily the place of each in the section when at length I proceeded to examine and measure the different beds, in order to settle the chronological sequence they followed and the conditions they typified.

I shall quote the sections in Thornton Old, or No. 1, Quarry in detail, and in descending order, as the strata in it were more complete than in the others.

I measured it on August 16th, 1868—

		Feet.	Inches.
	Boulder-clay,	12	0
1.	Supposititious limestone,	1	0
2.	Black shale with oolitic nodules,	6	0
3.	Limestone (capstone of the quarrymen),	3	0
4.	Soft black shale, lower half fireclay,	0	11
5.	Ash-bed made up of:—		
	Ash, 6 to 8 inches,		
	Bandstone, 19 ,,	3	10
	Ashy shale with soft shale, 5 ,,		
	Bandstone, 14 ,,		
6.	Grey shale,	1	2
7.	Coprolite bed, with square nodules,	0	7
8.	Fish-scale shale (bituminous),	0	6
9.	Green shale, with fish spines and encrinites (marine),	0	2
10.	Ironstone,	0	4
11.	Fireclay,	0	3
12.	Ironstone,	0	4
13.	Entomostracan shale,	0	2
14.	Black shale and fire-clay,	0	7
15.	Limestone (impure),	0	7
16.	Shale with fish palates,	0	2
17.	Limestone,	1	2
18.	Shale (parting),	0	0
19.	Limestone,	0	9
20.	Shale (parting),	0	0
21.	Limestone,	2	8
22.	Shale (parting),	0	0
23.	Limestone,	4	8
24.	Hard shale,	0	7
25.	Soft black shale with fossils (marine),	2	6
26.	Ash-bed, with large pebbles, so far as visible	9	0

From the detailed description recorded in my note-book, I shall

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now quote such remarks as may make the sections, and the conditions represented in them, more intelligible.

Boulder-clay. Light and loose in texture, but doubtless genuine, as in Thortonhall Quarry the limestone on which it directly lay was intensely glaciated.

1. Supposititious limestone, inferred from loose blocks lying upon the next bed.

2. Black shale, crowded with fossils. In Thornton Old Quarry it was 6 feet in thickness, but in Thornton New Quarry it was nearly double that. It contained many nodules of ironstone, which on the outside appeared as if of oolitic structure, but in the inside were as compact and hard as iron.

3. Limestone (capstone), with no fossils. This limestone and the shale above are the Hosie limestone of Mr. Neilson.

4. Soft black shale, lower half fireclay. This bed is important as representing a land surface. From it descend into the next bed innumerable rootlets of plants, apparently Stigmarian, which exist as black stripes among the grey ash.

5. Ash-bed. That this bed represents a period of volcanic activity there can be little doubt, as the greater part of it is composed of volcanic débris. Mixed with the ash is much shaly matter, showing that the ash fell into water into which ordinary sediment was carried by water currents while the ash was wind-borne, and both were deposited by gravitation. In the midst of this ash-bed occur large concretions of very hard compact stone, which are locally known as "bandstone." They are permeated by rootlets; perhaps they were originally nests of irony mud which collected in hollows of the ash-bed.

6. Grey shale. Had also the appearance of being mixed with ash, but more as dust than pebbles. There is nothing organic in it.

7. Coprolite bed with large square nodules. This was the most interesting bed in the section. The coprolites were numerous and good, as already stated. The nodules were also numerous, and in parts the bed was almost made up of them.

8. Fish-scale bed, bituminous. It was spoken of by the quarrymen as a coal, meaning thereby that it burned in the fire, and Mr. Thomson called it an oil shale. It was full of fish scales, small rhomboidal scales, which seemed to be in millions. There

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were also large scales, Mr. Thomson getting one 1½ inches in diameter, and Mr. Armstrong one double that. It had much vegetable matter associated with it, showing, I think satisfactorily, that it was of fresh-water origin. It was very fissile and tough.

9. Green shale. Very tough, and in all the other quarries except Thornton Old Quarry, it broke up into grains. It is in this shale that the fish spines, which are common here, occur. As on the surface of the slabs some truly marine fossils were found, such as small ossicles of encrinites, *Spirifera bisulcata*, and spines of *Producti*. We must suppose these tell of an invasion of the sea in a region of land surfaces and fresh-water lakes.

10. Ironstone, 4 in.
11. Fireclay, 3 in.
12. Ironstone, 4 in.

These are grouped together as in Braehead New Quarry, and in No. 2 Quarry, Thornton; the ironstone is not divided, and is 7 inches in thickness.

13. Entomostracan shale. This consists of black mud with cases and casts of *Leperditia Okeni* in single valves, which are sometimes felted like seed-cases in oil-cake. In Thornton No. 1 Quarry this shale lay immediately under the lower ironstone, and was only 2 inches in thickness. In Braehead Old Quarry it lay in a bed 28 inches in thickness, of a soft black shale-like fireclay, and was 7 inches in thickness. In Thornton No. 2 Quarry the entomostracan shale was absent, and the bed it should have been in was 14 inches in thickness.

14. Black shale and fireclay, 7 inches, contained petrified plants, stems, and fruit-like bodies, one a cone of *Lepidodendron*, and in Thornton No. 2 Quarry Stigmarian roots 4 or 5 inches in diameter, composed of ironstone.

15. Limestone, impure, 7 inches. This is the first marine bed that occurs below the fresh-water series. The chief fossils were small ossicles of encrinites.

16. Shale, with palates in extraordinary numbers. I have recorded *Psammodus porosus* and *Cochliodus magnus* perfect, with many others, sometimes twelve or a score being got at a gathering.

17 to 24.

The divisions of the main post of limestone. Being hard and compact, few fossils were got from them, but I have a record of *Productus giganteus* 4 or 5 inches in length.

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25. Soft black shale. Marine fossils of well-marked Carboniferous types were abundant in it.

26. Ash-bed, with large well-rounded pebbles in parts like a conglomerate. In Thornton Old Quarry 9 feet of it are visible. In the railway cutting south of the quarries 20 feet are visible, and in Kittoch Glen 50 feet of it are seen in the cliffs.

The foregoing is a summary of what I saw and found in these quarries in 1868, and I recount the story in order that the members of the Society might know of it, and, knowing it, might direct further researches to those parts where things not got before might be met with.

The parts which represent the land and fresh-water conditions are those which, I think, might be most profitably examined and studied, in preference to those laid down under marine conditions, which have already been thoroughly worked out by Mr. Neilson in his paper previously referred to.

But with the middle portions of the sections—the shale, the bandstones, and the ironstones lying between the two limestones, more might yet be done, as witness the recent finding of the cranium of a reptile by Mr. James Anderson, lately exhibited by Mr. John Young. For this purpose the sections might be examined more thoroughly than I did, as being essentially a searcher of shale heaps I did not quarry, but simply took what the quarrymen and the weather gave freely to my hands.

In the old quarries of Braehead and Thornton the output of shale was extensive, and much of it was buried up again ere it was thoroughly weathered. Explorations might yet be made into these old shale-heaps and the shale-blocks taken out and examined for the peculiar fossils yet remaining in them.

Another suggestion is that the layer of shale, No. 16 in the section, might be sought for and quarried for the sake of the palatal teeth which might be found in it, as they seemed numerous enough to repay any such trouble. I have a record that, from a small quantity of it which I stumbled upon incidentally, I got about a dozen small palatal teeth, and after two or three weeks further weathering I got as many more. From this fact those who care for such fossils may know where to seek for them *in situ*.

The next bed to which I may direct attention is the great bed of ashy conglomerate, which underlies the main limestone. It

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can be seen on the left side of the cartway to the mouth of the old disused kiln at Thornton. It was visible all the time I was searching the quarry heaps, and I often took a look at it as a contrast to the fine shale above that limestone. It seemed to belong to a different world—a world in which nothing was to be seen or heard but "water breaking on stone,"—as the water-worn grit and pebbles were the only things in it that indicated the circumstances of the times in which they were deposited. In Thornton Old Quarry about 9 feet of this bed were visible, and in the railway cutting south of Thornton a hummock of it, about 20 feet in thickness, was cut through. In the latter exposure all the peculiarities which distinguish it are better seen, and its character as a great deposit of volcanic débris, washed, moulded, and assorted by water, is manifest at a glance. In the Kittoch glen, near the mill, cliffs of it about 50 feet in height were seen by me in 1872.

In the Geological Survey maps of the district (Lanark, Nos. 16 and 10, 6-inch scale), this conglomerate is shown as a band 150 yards in breadth, extending along the south side of East Kilbride parish for a distance of 5½ miles, from the eastern edge of sheet 16 to the fault at the junction of the Kittoch Water with the White Cart. But in the neighbourhood of Thornton, Brachead, and Phillipshill it has a breadth of about half-a-mile, and a superficial area of about 2 square miles. As the surveyor who mapped the district, Dr. James Geikie studied its character and origin much better than anyone giving only casual glances at it. His description, as contained in paragraph 40 of the "Explanation" to sheet 23, 1-inch map, may be fitly quoted—"The igneous rocks (those of the Eaglesham hills) are, where no faulting intervenes, invariably fringed with a set of conglomerates, tufaceous or ashy grits, sandstones, shales, &c., which may be considered either as the top beds of the volcanic series, or, perhaps with greater propriety, the basement beds of the Carboniferous limestone series. . . . Their general character is that of dull meagre yellow and yellowish green tufaceous grits, shales, and sandstones, with beds of red and mottled laminated tufaceous clays, and in some places courses of conglomerate, the stones of which have been derived from the adjacent trappean masses. In some portions the beds

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are calcareous and contain abundant fossiliferous remains. They are exposed at Benthall Rig and West Drumloch, where also the overlying main limestone is opened in quarries. An excellent section also is laid bare in Kittoch Water, which has cut through the conglomerates, and exposed the underlying igneous rocks. They are likewise well seen in a brook at Laigh Walkerdyke, and again at Strathaven, while an excellent section is laid bare in the stream at West Rylandside near Drumclog. There the deposits consist of a considerable thickness of brown and red mottled ashy fireclays and mudstones, which are here and there charged with small rounded stones. With these beds are associated thin limestones and calcareous shale (full of Carboniferous limestone fossils), grey and white sandstones, dark shale, thin coal and fireclay.

"The origin of these deposits is sufficiently evident; they have undoubtedly been derived from the tear and wear of the underlying igneous rocks, and indicate the old shore-line of the Carboniferous limestone sea. It would thus appear that, after the igneous forces which had given rise to the trappean rocks of the district became nearly or altogether quiescent, a long bank of land stretched westward from Strathaven, and was washed by the sea along its borders. The deposits laid down at this time form the passage between the Calciferous sandstone series and the overlying Carboniferous limestone, but they appear upon the whole to be more closely connected with the latter than the former."

In confirmation of the statement that in some portions "abundant fossiliferous remains" occur, I may refer to page 58 of the same "Explanation," where a list of ten species of common Carboniferous fossils is given, from "shale bands in ash below main limestone," at Shieldburn near Benthall. I may also mention that Mr. Neilson, in the paper already quoted, gives a list of about forty species of the most characteristic Carboniferous fossils found by him in the black shale, which in Thornton Quarry lies immediately upon the ash conglomerate. From both these instances we may gather that this conglomerate truly represents the "shore-line of a Carboniferous limestone sea."

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No. XXI.—The Leaf-Caves of Mull. By John Dougall, M.D., Professor of Materia Medica, St. Mungo's College, Glasgow.

[Read 12th November, 1891.]

These leaf-beds, or leaf-caves as they are locally called, were first made known by the Duke of Argyll in 1851.* They are situated on the south shore of Loch Screden, which lies on the west side of Mull, having near its entrance, and almost opposite, the famed island of Staffa. This part of the boundary of the loch forms a low basaltic promontory called Ardtun, which has on its other side a wide land-locked bay, at the head of which stands the village of Bunessan.

The leaf-caves are about 2 miles from the village, and are of easy access; but to see them to advantage the tide must be on the ebb. I believe that there are three caves to be found within a short distance of one another, but as it so happened during my visit that the tide was flowing, I only saw one of them, though that was fortunately the one where the fossil leaves are chiefly to be found. It can now scarcely be called a cave; it is more properly a huge fissure, or small gorge, which slopes through the sea-cliff to the tide-level, and to which access is therefore comparatively easy. That it once, however, has been a cave, in the strict sense of the word, is easily seen by an examination of its structure, and by observing its situation. The huge breakers which expend their strength upon this rocky wall during a north-west gale are quite sufficient, if time enough is conceded, to produce the effects observed. In this case the strata have first been tunnelled by the waves into a cave, and this being enlarged gradually by the same process, the roof fell in, and the small gorge which presently exists was thus formed.

In descending this gorge from the cliff above, the first thing which attracts attention is a bed of conglomerate about 4 feet thick. It lies nearly horizontal, and consists almost exclusively of jaspers and the usual varieties of flint pebbles, some as large as an orange, and all very firmly cemented together. In Jukes' "Geology," 1854, this rock is said to consist of "burnt red and yellow chalk flints." In some portions I also observed small

* I am informed by Dr. M'Kechnie, of Bunessan, Mull, that they were really discovered by Murdoch M'Quarrie, who afterwards went to Melbourne.

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angular bits of chalk limestone similar to that found on the coast of Antrim.

Further down the gorge is a large accumulation of blocks and slabs of what appears to be indurated shale; most of these are, I believe, the result of a series of blasting operations made a few years ago by Mr. Starkie Gardner, F.G.S., at the instance of the Duke of Argyll. This stratum of shale contains the leaf-bearing beds, and the object sought to be attained by the blasting was a more thorough examination of them than any which had hitherto been made. Amongst these shale blocks I found some fragmentary portions of leaves and what I took to be part of a fern, probably the *Filicites Hebridicus*, as figured by Jukes. As I had neither hammer nor chisel with me on the occasion of my visit, I had to be content with picking up specimens that some former visitors had either overlooked or had intentionally left.

On getting down to the sea-level a scene is presented to the eye which I think no one who has ever seen it, be he geologist or not, can ever forget, and the massive grandeur and wonderful form of which no oral or written description, however minute or graphic, can convey more than a faint idea. I have seen the Giant's Causeway, Fingal's Cave and the Clamshell Cave in Staffa; all of these are doubtless on a larger and more imposing scale than the aggregation of columnar basalt to be seen at Ardtun, but, so far as my memory serves me, their columns do not assume anything like the same variety of positions—horizontal, vertical, angled or arched—nor are they so distinct in their outlines.

In any case, there is to be found here as varied and striking an exhibition of columnar basalt, and one which affords as magnificent examples of basaltic crystallization, as can anywhere be met with.

Standing apart from the sea-cliff, and a short way into the sea, is a large coniform mass of rock, the base of which consists of basaltic columns and the upper portion of volcanic ash. It bears some resemblance to the sea-stack in the north-west of Orkney, well known as the Old Man of Hoy.

According to the Duke of Argyll the whole of the Outer Hebrides is composed of Laurentian gneiss, and it "is the basement upon which are piled the mountain ranges of the north-west of Scotland." He goes on to say, "The Mull mountains are composed almost entirely of volcanic rocks; yet not a vestige remains

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of the volcanic vents from which those great masses of melted matter have been poured forth. Some of the trap mountains of Mull lie on beds of the old crystalline Silurian rocks; others of them are piled on strata of the Oolite and Lias, while others cover the débris of chalk, and may range through many of the Tertiary ages."

The basaltic promontory of Ardtun already mentioned has revealed in its leaf-beds that "once there existed on this area some great country covered with the magnificent vegetation of the warm climates of the Eocene* age." These remains are thus believed to bridge over in some degree the great gap between the Cretaceous and the Post-cretaceous or Tertiary ages. "Nothing of that country or of its vegetation now remains except a few autumnal leaves impressed upon the clays of some ancient river, or shallow lake or marsh, and sealed up under sheets of lava." The whole of it has "foundered amidst fanatic storms," or has been disintegrated chiefly by the ocean, which Hugh Miller speaks of as "that blue foaming dragon whose vocation it is to eat up the land." Even of the new surfaces which were formed out of the volcanic outbursts there remain only a few fragments broken up into capes and headlands and "caverned islets in the sea."

The succession of the beds as seen in the gorge which I visited is, according to the Duke of Argyll, as follows, in descending order:—

Uppermost basalt, ...	40	feet.
First leaf-bed, ...	2	"
First ash-bed, ...	20	"
Second leaf-bed, ...	2½	"
Second ash-bed, ...	7	"
Third leaf-bed, ...	1½	"
Amorphous basalt, ...	48	"
Columnar basalt† to low tide level, ...	10	"
	131	feet.

The bed of conglomerate which has already been alluded to is associated in one place with the first ash-bed. A thin seam of

* Jukes, *op. cit.*, says "Miocene."

† The basaltic columns are now at least 30 feet in length.

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coal is also found in one place underlying a sheet of basalt, and has been thought to be the accumulation of the vegetation forming one of the leaf-beds.

By some observers the ash-beds are described as resembling the tuffs of Mount Dor, Vesuvius, and Madeira; the leaf-beds as composed of baked clay or very fine mud. This may be judged of to some extent from the specimens which I now exhibit.

A collection of the leaves obtained at Ardtun was exhibited by the late Professor Edward Forbes, who said of them, "The general assemblage of leaves is decidedly Tertiary, and most probably of that stage of Tertiary termed Miocene. Their climatal aspect is more mid-European than that of our Eocene flora. There is a striking resemblance between some of them and fossils from Styria and Croatia."

These plant remains have been referred to various genera and species, comprising plane, yew, alder, and rose (leaves), equisetum (stems), chestnuts, conifers, and palms, a plant common in Japan named *Salisburia*, a fern, *Filicites Hebridicus*, and several other vegetable forms.

No. XXII.—Peculiar U-shaped Tubes in Sandstone near Crawfurdland Castle and in Gowkha Quarry, near Kilwinning. By John Smith, *V.P.* With an Illustration. [Plate No. X.]

[Read 12th February, 1891.]

Two years ago when examining the sections exposed in the Crawfurdland Burn, near Crawfurdland Castle, 2 miles north-east of Kilmarnock, I observed on certain parts of the sandstone rock a number of peculiar U-shaped markings, with which I was not at all familiar. A portion of the sandstone containing one of these markings, which I detached from the rock, was placed in the Hunterian Museum, Glasgow, and Mr. Young informed me he had never seen any similar markings before, suggesting that I should send a note on them to the Society. Lately, when in the Crawfurdland district with Mr. Carrick, I made a more minute

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examination of the beds, and found the section exposed on the west side of the Crawfurdland Burn to be as follows:—

		Feet.	Inches.
	Shaly coal,	0	10
	Fireclay,	0	10
	Broken sandstone,	0	5
A.	Dark sandstone, with a few U-shaped markings and some plant rootlets,	3	4
	Shale parting,	0	1
B.	Very dark sandstone, with many U-shaped markings,	0	10
C.	Dark sandstone plies, with a few U-shaped markings on upper ten inches,	2	3
	Dark shale,	1	4
	Splinty coal,	0	4
	Coaly shale,	0	8
	Sandy fireclay,	2	0
	Yellowish sandstone, forming bed of stream.		

The beds dip to the south as shown on section [Plate No. X.], and the U-shaped markings are first seen here and there in the top part of bed C. The animals which formed the markings had commenced to dig into what was probably for the time being the bed of an estuary, and continued to live in that position till further sedimentation buried up their homes, when they or their descendants again began to dig and form fresh habitations in the overlying bed. In the section at Crawfurdland this process has been repeated many times. Bed B is literally crowded with them, and on breaking off some of the more shattered parts of the rock-face, the markings are seen to have the uprights of the U always at right angles to the plane of rock-bedding, and the plane of the U's lies to all the "airts" of the compass.

The only other fossil U-shaped tubes with which I am acquainted are those from the Cambrian sandstones named *Arenicolites didymus*, and the U-shaped tubes formed by the living amphipod crustacean, *Corophium longicorne*, which are abundant in the muddy sand in the lower part of the estuary of the Garnock Water below Kilwinning. In both of these instances the habitation of the animal has been formerly and is now a simple U-shaped tube. But the

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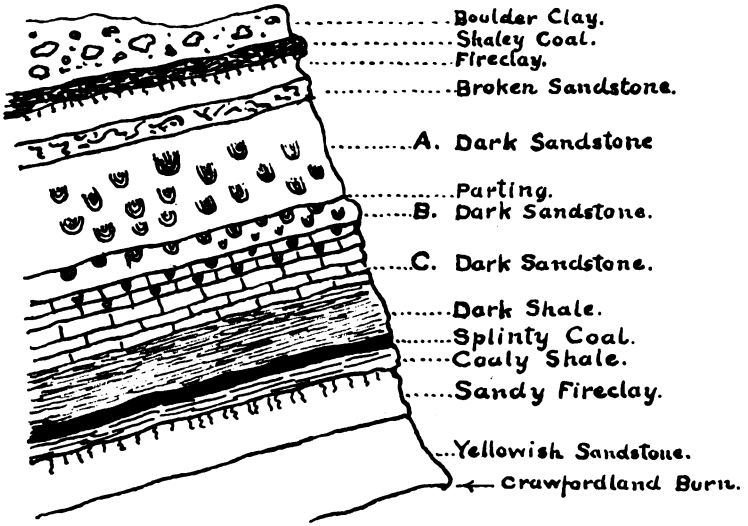
COROPHIOIDES POLYUPSILON, Smith, sp. nov., full size.



J. SMITH, DELIN. SECTION SHOWING POSITION OF U-SHAPED TUBES. CARTER & PRATT, LITH.

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U-shaped tube markings on the sandstone of Crawfurdland and Gowkha are very different.

Beginning as a simple U-shaped tube of about 1½ inches wide by the same in height, the animal appears to have enlarged its tube or habitation to accommodate its increasing circumstances till it reached as much as 4 inches wide and 5 inches high, these being the largest measurements I have taken. Between these extremes they are to be met with of all sizes. In these cases the animals appear to have been cut off by sedimentation or by other causes. They resemble a lot of distorted and crushed up U's of different sizes, placed one within the other. To enable the animal to form this structure it has apparently broken through the outer and under sides of its tube and has reformed its habitation, in some cases as many as eight times. It is therefore only the last dwelling-place or the largest outer U that is preserved in an entire state, though this is not always the case. This shows that at this stage the tube was circular in section, and from ¼ to ⅜ths of an inch in diameter.

It is, of course, impossible to tell what kind of animal formed these peculiar tubes; the only living one which forms a U-shaped tube with which I am acquainted is the little amphipod crustacean already mentioned. The sandstone rock in which the tubes occur is of course one of the worst kind of matrices for preserving organic remains, especially the delicate parts of amphipods. If the tubes were formed by annelids, which I do not think is very likely, it might yet be possible to discover their horny jaws. But even this is doubtful.

The U-shaped *Arenicolites didymus* found in the Cambrian strata of the Longmynd, where, like the tubes of the Garnock *Corophium*, they occur in thousands, are thought to have been the habitations of annelids (Nicholson's "Life History of the Earth"), but I think it is more likely that the tubes now under notice were constructed by crustaceans. Gosse remarks of *Corophium longicorne* that it comes out of its burrow and beats about on the mud with its long antennæ, but although I have many times visited the estuary of the Garnock, where these little crustaceans have their homes, I have never seen them do this. On taking up their U-shaped tubes, which, from the upper part of the tube to the bend, are between 1 and 2 inches long and very

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slender, with just enough of mucus plastered on the inside to keep them together, it is found that by breaking them and looking through the upper part a small hole, which would do little more than admit a pin, has been left, and it is very likely that the little crustacean keeps up a circulation of water through its habitation by drawing it in at one end of the tube and forcing it out at the other. This is probably to supply it with oxygen for breathing and with "small fry" for food, although it has got the reputation of catching and devouring animals much larger than itself. To see these small openings in the ends of the tube the operation must be very carefully performed, and the surrounding wet sand must be left about it, as the tubes are so fragile that they will not, when bared, sustain their own weight.

The U-shaped markings at the Gowkha Quarry, north-east of Kilwinning, are scarcely so large as the Crawfurdland specimens, but evidently belong to the same species, and appear to occur at the same geological horizon, as the Highfield or Clonbeith limestone, one of the upper beds of the Carboniferous limestone series, is found at a short distance above the beds in which they are contained. As I previously remarked, I think it is very likely that these peculiar structures have been formed by a crustacean, and have therefore named the fossil *Corophioides polyupsilon*, Smith, *sp. nov.*

The *Arenicola piscatorium* or lob-worm, much used by the fishermen for bait, lives in the sand in estuaries, and on the sea-shore between tide-marks. It inhabits a hole which opens on the surface at both ends. One end is called by the fishermen "the eye," and from the other are thrown up those peculiar sandcasts so abundant on many of our shores. The tube of this animal is rather bow-shaped than U-shaped.

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No. XXIII.—The Sand-hills of Torrs Warren, Wigtonshire. "*Wo der Sand der Dünen Weht.*" By John Smith, *V.P.*

[Read 10th December, 1891].

From Glenluce to Sandhead, in Wigtonshire, a distance of about 6 miles, there stretches a line of sand-hills of varying breadth, narrow at both ends, but widening out to about one mile and a-half towards the middle. Torrs Warren occupies a central position in this district, and within the last ten years has been rendered famous by the number of archæological relics that from time to time have been discovered in it.

As to the name "tor," it is evidently the Celtic for a hill or knoll. We have Torbolton, the hill of the baal fire; Tormore, the big hill; and the Torbane, vulgarly called "The Rumple."

The other day I visited this famous locality with a friend, and spent a few very interesting hours wandering over its ever-varying surface. There is perhaps no other place in the West of Scotland where a few such quiet hours can be spent, for one may wander about to his heart's content without seeing a single individual, or even a "footprint on the sands of time," with the exception of those he is impressing at every step, and which the next breath of wind will effectually blot out of existence, or perhaps cover up with the drifting sand and preserve for ages.

The very first thing that catches the archæological eye on entering Torrs Warren is the immense quantity of flint chips interspersed amongst the gravel which may be seen wherever a sufficient quantity of sand has been blown by the wind from any particular spot. In fact, before the use of phosphorus matches became so common, this locality was the great magazine to which the people of the surrounding neighbourhood used to resort when they required to lay in a supply of flint to use with the "fleerish" or steel, and tinder or touchwood, or, at a later date, with match-paper, to obtain a light.

But the old prehistoric men had no steel wherewith to strike fire with flint; though they had discovered another substance, which they called pyrite or firestone, and with it and a bit of flint they were able to produce fire. Bits of this pyrite are frequently found in old graves, or in the earthen urns got in them. In fact our word "fire" is just a form of the first part of pyrite, viz., "pyr."

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We have also this word "pyr" in pirates, or the fire-raisers, who very likely carried on their depredations on land before they took to the seas, and in funeral "pyre;" and we shall see by and by that in the tors the funeral pyre must often have been lighted. In fact the word funeral has not yet passed out of common speech, for instead of people saying they are going to a burial, they quite as often say that they are going to a funeral, as if the body was going to be ourned.

Torrs Warren presents us with many pictures of a type that have not yet found their way on to canvas; for variety they completely take precedence of our much smaller Ayrshire sand-hills nearer home. As in all moving sands, we have the recently-drifted part with its long smooth slopes and exquisitely curved outlines, in places covering the bent half knee-deep or, it may be, drowning it completely. One knows in a moment when he has got on to a newly-drifted part by at once sinking over the shoe. The part from which the sand has been drifted presents quite a different aspect. It is weather-beaten, and behind each bit of straw, stone, or other hard material there is a trail of sand, generally covered with fine dust, while here and there a small stone is seen perched upon the summit of a short pillar of sand. If the hill is bent-covered at such a place, the slope is as steep or even steeper than that of a railway bank.

In Torrs Warren there are generally three layers of soil found at different levels. The bottom layer may be seen cropping out on the side of a sand-slope, and perhaps placed 20 or 30 feet above the gravel and flint-debris-covered bottom of a hollow between two hills. The second layer is generally a few feet above the first one, and the third is just below the growing vegetation covering the hills. From their dark colour these layers of soil are very conspicuous, interbedded, as they are, with the light grey sand. Of course they have derived their colour from the growth and decay of the varied vegetation which has covered many parts of the Torrs. Where the drift of sand has been slow, a layer may be 6 or 8 feet deep, but it is generally much thinner, often not a foot in thickness. A very marked feature in connection with these soil-layers is that the flint chips and implements occur only on the top of the *bottom layer;* and in no instance did we see them above any of the others, though, of course, where the bottom

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layer has been blown away the flints have found their way down to the Raised Beach gravel. On the top of the lowest soil-layer it was also noticeable that very few stones were to be seen, and such as there were had in all likelihood been brought there by human agency. In fact the bottom soil-layer seems to lie on top of the old Raised Beach (possibly beaches), and it is only from the sand underneath it that the beach pebbles have been derived.

Nearly every flint one finds amongst the Torrs occurs as a chip, and these chips are innumerable. Sometimes we pick up a core from which flint flakes have been struck. The chips and cores are just the remnants left over after the more suitable pieces have been taken off for implements or weapons. The old Ayrshire flint-worker would have been glad of many of these chips, for flint seems to have been much more common in Wigtonshire than in Ayrshire. On the sands of the Torrs are to be seen, here and there, unbroken pebbles of flint. That all the flints have originally come from the stratified beach beds I think there can be no doubt. Small flint nodules have been picked out of the beach beds near Dunragit, which is just what we find in Ayrshire, but the proportional quantity of flint there is much less than at the Torrs, the reason appearing to be that the latter locality was much nearer the source of supply than Ayrshire.

I once ventured the opinion, when treating of the Ayrshire flints,* and have since seen no reason to change it, that the flints of the West of Scotland have been brought from the North of Ireland, the transporting agency having been sea-weed. It has been suggested that such flints may have been brought from Ireland by ice, but we have no evidence that ice was present in our seas during the Raised Beach periods. There are *no glacial shells* in the Raised Beach beds. In fact their fauna indicates a temperature as mild as that of the present day; and it appears to have been during this period that the gigantic oaks, the remains of which are found under our peat mosses, flourished all over the land.

It has also been suggested that the flints are of native origin, derived from a Chalk formation which once covered part of the south-west of Scotland. But the great difficulty with this theory is that no flint has ever been found in the Boulder-clay. It is, however, possible that we once had a Chalk formation, the remains

* *Transactions*, vol. vi., p. 185.

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of which were completely swept away during the first advances of the great glacial sheet.

The Torrs' flints are generally of a light greyish colour. Some of them are yellowish, or even reddish, like the bulk of the Aberdeenshire flints, and a few are dark coloured, occasional bits being almost as clear as glass, but with a slight milkiness. During my visit I picked up a few small pieces of the real Irish white chalk-limestone, and I have seen similar specimens amongst the Ayrshire sand-hills.

It was interesting to note the variety of vegetation which grows on these barren sand-hills; certainly not barren as regards certain kinds of plants, which are in sufficient abundance to support a quantity of rabbits, and, what we did not expect to see, a considerable number of grouse. There is, first, the inevitable bent or marram, *Psamma arenaria*, which seems to thrive best when it is much covered up, in fact almost drowned, by the drifted sand. Here and there, but not so abundant as the bent, we find the sea-sedge, *Carex arenaria*. The stem of this plant keeps under the sand, and runs along for several yards in a nearly straight line, sending up at pretty regular intervals a few green blades and an occasional flower-stem. The little silky willow, *Salix fusca*, commands attention from the peculiarity of its growth. Sometimes we see it covering considerable areas as with a carpet. At other times we find it in detached clumps of a circular or ovoid shape, which rise into small dome-like masses. Sometimes these clumps assume considerable proportions, 12 to 20 feet in length, standing clear up from the sandy floor to the height of 6 or 7 feet; some of the more elongated ones, as seen from a short distance, resembling immense hedgehogs.

The field thistle, *Cnicus arvensis*, is found in considerable patches, and it seems always to prefer the hollows amongst the Torrs, where it looks like a plantation of young fir trees. In fact, so striking is this resemblance that a close inspection had to be made before we were satisfied that we were mistaken, its growth being somewhat modified by the rabbits having nibbled at it. Two species of heaths, *Erica cinerea* and *E. tetralix*, the fine- and the cross-leaved heaths, are abundant on certain parts, the former predominating. *E. tetralix* had ceased to flower, but the fine-leaved heath still held forth a gorgeous show of crimson flowers.

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Both these plants seem to be little, if at all, touched by the rabbits. It was quite different with the heather, *Calluna vulgaris*, which was cropped to the very ground, and in many places looked as if it had been literally shaved with a razor. This plant seems to be a tit-bit with several animals. Sheep and grouse feed largely on it. "Ye grouse that crap the heather bud." In some parts of the Torrs the heather has assumed a very peculiar and striking form. This appears to have resulted from the combined action of its own growth, the dew, the sand, and the rabbits. At these places the heather is found in dense sub-globular clumps, which stand prominently up from the sand, or from other surrounding herbage. These clumps vary from a few inches to several feet in diameter, and give to this part of the landscape quite a foreign appearance which, if put on canvas, would scarcely pass in an art gallery as having been taken from any scenery that this country possesses. The genesis of these "heather dumplings," if I may be allowed the expression, appears to be this. The dew having wetted the heather, the drifting sand adheres to it. After a few days of calm weather the plant sprouts a little without the young shoots getting dusted with sand. These young sprouts are immediately nibbled off by the rabbits, so that, like an oft-clipped hedge, the heather, finding it cannot grow freely outward, forms a dense mass. Repetition of this process during a number of years—the dew, the coating of sand, and the constant and careful attention of the rabbits—has produced these peculiar dense clumps.

Certain parts of the Torrs are covered with a dense carpet of mosses of lovely shades of green, and at other places we see patches of sheep fescue grass cropped as close as a well-kept bowling-green. Ragweed, Isle of Man cabbage, bladderwort, and the lovely pansies all so common on our sand-hills, were conspicuous by their absence. But as the Torrs Warren is extensive, and it would take several days to visit every nook and cranny in it, it may have been that during our short visit we had not reached the "region" of their growth.

From the Torrs Warren within the last ten years an immense quantity of prehistoric antiquities have been collected. Thousands of flint implements and weapons, including arrow-heads, saws, scrapers, borers, hammers, flakers, &c., have been got. A number

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of stone celts, some of them made of a material not found in this country, indicating a commercial intercourse with, if not actually an invasion by, some foreign people, have been found, also hammer-axes of various patterns, perforated to receive a wooden shaft. Stone melting-pots have been laid bare by the drifting of the sand, and fragments of ancient pottery, with an occasional complete urn, have been found. Our "finds" during our short visit, though not great, were not to be despised. We obtained a few worked flints, a "chapping-stone" hammer, as the natives term the conventional hammer-stone, a stone polisher, and some fragments of ancient pottery. We also got a coin about the size of a sixpence, made of a very brittle white metal, which was unfortunately broken under the impression that it was a thin bit of stone. On close inspection some of the ornamentation can still be seen, and I have no doubt that in the hands of an efficient numismatist it could be made out.

We also came across the remains of two ancient ironworks, and the slag-hill of the larger one contained about 10 cwt. of heavy black slag, scarcely to be distinguished, unless from its unique appearance, from the "bulldog" of the modern furnace. These ancient furnacemen perhaps did not know the use of lime, or if they did they may have discarded it. Their process of manufacture was probably similar to that still practised in the interior of Africa, as follows:—Two skins worked alternately give the necessary blast, a rapid action producing malleable iron, and a slow one giving steel, the iron having time to absorb a sufficient quantity of carbon. Wood reduced to charcoal would perhaps give the necessary fuel, and in corroboration of this I found a bit of the slag with several cavities where pieces of wood charcoal had once been imbedded in it, the fibrous appearance of the wood still showing on the slag. We subsequently learned from the rabbit-catcher that when this old furnace-hearth was at first blown bare, numerous pieces of burnt clay of a material resembling the ancient pottery was dug up on the spot by him. The slag is quite similar to the pieces which turn up now and then on the Ayrshire sand-hills, and to that which I obtained from the top of the Ardrossan shell-mound.

On some parts of the Torrs, covering small areas, nearly every stone to be seen is angular, presenting the look of having at

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one time been heated red-hot. Unless such had been the case, it is difficult to account for their appearance. I think it is not unlikely that these stones mark the localities where the prehistoric people had their huts, and that the stones having been repeatedly used as heaters, by being made red-hot and plunged into the water to be heated, had split in the process. They appear not to have had any kind of dish that could withstand fire-heat without breaking in the process. No remains of ancient dwellings have ever been found amongst the Torrs, but small pavements formed of water-worn stones have sometimes been blown bare, and most probably had formed the floors of huts. Occasionally the very spots where the old flint-tool manufacturers worked have been exposed, the implements and materials which they used lying as they had left them, such as an old piece of pottery holding the flints, a stone anvil and a hammer, both considerably battered by usage, numerous flint-flakes which had not been considered good enough to convert into tools or arrow heads, and all bearing strong evidence that the old flint-worker had carried on his manufactures in the locality.

On a flat part of the Torrs we came across a circular ring of stones, which would be about 6 feet broad, and the circle ten paces in diameter. The stones were all water-worn, and 3 to 5 inches in size, a large proportion being of white quartz. In the centre of the ring was a number of calcined bones. From these appearances we came to the conclusion that this had been a burial ground, and we subsequently learned from the rabbit-catcher that when first blown bare of sand he had obtained from the inside of the ring two urns filled with calcined bones. The bones had been broken into pieces about the size of a finger, so that they might be more easily packed and take up less space in the urns than if they had been left entire, or as the fire had left them. Over the urns had in all likelihood been raised a small mound of sand, and the water-worn stones appear, from the position in which they now lie, to have been placed round the bottom of the mound and partly up the sides, but not carried right over the top. They had probably been used both as a protection against the wind and as an ornament to the mound—its top being probably turfed over; and certainly this simple and primitive grave, which very likely held the remains of some of the chiefs of the people,

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would look quite as well as many a more imposing structure. It is difficult to understand what could have first led these primitive people to adopt such a terrifying process as the burning of their dead relatives. Was it done from sanitary considerations, or to prevent the bodies from being devoured by wild beasts?

The urns found within this ring are now in the Museum of the Society of Antiquaries of Scotland, as well as many hundreds of the flint implements, &c., found amongst the Torrs. In one place, along with the calcined bones, was got a bronze dagger, a polisher, and four white quartz pebbles. Some speculation has been ventured as to the significance of white pebbles as accompaniments of burials. The use of white pebbles as a happy symbol seems to be very ancient, and the Romans had their *calculi candore laudatus dies*, as memorials of happy days well spent. It has been suggested that white pebbles were placed only in the graves or urns of those who had lived an exemplary life, and if so the ancient of the old Torrs who got four white pebbles placed in his urn must have been a very worthy individual. It is not unlikely that this ancient custom suggested to the writer of the Book of Revelations—"To him that overcometh will I give to eat of the hidden manna, and will give him a white stone, and in the stone a new name written, which no man knoweth saving he that receiveth it." The "black balls" at ballots of the present day are just a continuance of the ancient practice; when a condemned criminal received his sentence there was handed to him a black pebble.

As to the genesis of the Torrs, they have, like the Ayrshire sand-hills, had two origins, the greater part of the sand having been derived from the 21-feet beach and the rest from the present sea-shore. To every person who possesses a camera, or a paint-box and a brush, and knows how to use them, we would say, visit the Torrs Warren. The first train from Glasgow lands you at Dunragit Station at 9.20, and within half-an-hour's walk of the spot. No art-gallery of Scottish scenery can possibly be complete that does not possess a few views of the Torrs.

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No. XXIV.—Notes on the Group of Carboniferous Ostracoda found in the Strata of Western Scotland, with a Revised List of Genera and Species. By John Young, F.G.S., *V.P.*

[Read 12th February, 1891.]

The work of discovery and after determination of the several genera and species of the fossil bivalved division of the Crustacea, termed Ostracoda, which are found in the Carboniferous strata of Western Scotland, has engaged the attention of several of the members of this Society for at least thirty years. Now that the group, so far as discovered, has been very fully determined, described, and figured, thanks to the long-continued labours of two of our distinguished honorary members, Prof. T. Rupert Jones, F.R.S., and Mr. James W. Kirkby, who have made its study one of their chief specialities, we are in a position to draw up for record in the pages of the Society's *Transactions* a more extended and correct list of these organisms than any yet given. Messrs. Jones and Kirkby have also been assisted in many of their determinations by Dr. G. S. Brady, F.R.S., a gentleman who has done a vast amount of good work in the investigation of the recent Ostracoda; his name therefore appears in the lists as one of the authorities for the names of several of the Carboniferous species.

The earliest record of shells from Scottish Carboniferous strata since determined as belonging to the Ostracoda, is that of the Rev. David Ure, in his "History of Rutherglen and East Kilbride," 1793, where, in plate XIV., he figures four species of "microscopic shells that can only with difficulty be perceived by the unassisted naked eye." Their true nature was unknown in Ure's time, but his mounted specimens, which still exist, are found by Professor Jones to belong to at least four genera of Ostracoda. For nearly sixty years after Ure's time nothing seems to have been done in searching our Western Carboniferous strata for further examples of this group.

It may be of interest to mention that up till 1865, some seven years after the formation of this Society, not more than five or six species of Ostracoda, including those found by Ure, had been recorded from the Carboniferous strata of Scotland. In that year Messrs. Jones and Kirkby issued the first of their series of papers on the Carboniferous Ostracoda; in one of

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their recent papers, that for 1886, they record no less than 107 species, belonging to 21 genera, found in the Carboniferous strata of Western Scotland, and they further state that Western Scottish strata "have yielded a great number of Ostracoda, more species, in fact, than any other portion of the Carboniferous system, either in Scotland, England, or elsewhere" (*Quart. Jour. Geol. Soc.*, London, 1886, p. 502).

If our Society takes any credit for the greater amount of work done by its members than seems to have been the case elsewhere, in searching the various local Carboniferous strata for this special group of minute organisms, the credit is, I think, greatly due to the encouragement continuously received from Messrs. Jones and Kirkby, through the series above referred to, with their several determinations and figures and descriptions of the newer forms. This series of papers, of which there are now fourteen, has appeared in the *Annals and Magazine of Nat. Hist.*, *Geological Magazine*, *Quarterly Journal* of the Geological Society, *Proceedings* of the Geologists' Association, and *Transactions* of the Manchester Geological Society, and forms the basis of a monograph on the whole group of which two parts have already been printed, for the Palæontographical Society, in 1874 and 1884.

When our members first began their searches for localities which yielded Carboniferous Ostracoda, the particular stratum from which Ure obtained his specimens was not known; all that he stated regarding their localities being "Laurieston and Stuartfield, East Kilbride," without any mention of the nature of the bed in which they were found, or their mode of occurrence.

In a letter to Professor Jones, dated 4th July, 1865, and printed in one of the papers referred to (in the *Annals*, 1866), I was glad to be able to announce the re-discovery of the stratum yielding the *Kirkbya Urei*, Jones, and the other species figured by Ure. This stratum is the now well-known bed of fossiliferous shale lying between the two posts of limestone, which extend over a considerable area of Blantyre and East Kilbride. This shale, after further investigation, has yielded several other species of Ostracoda, as well as many other forms of Microzoa, it being one of the richest for organisms yet found in the West of Scotland. The quarries where Ure found his specimens are no longer accessible, but there are others of more recent date scattered all over the district, and

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these will be found noted in the "Catalogue of Western Scottish Fossils," 1876, under the "List of Localities for Carboniferous Fossils."

The Ostracoda found in the Carboniferous strata of Western Scotland are obtained from certain fossiliferous beds, in each of its chief divisions, viz., the Calciferous sandstone series, the lower limestone series, the lower coals and ironstones, the upper limestone series, and the upper coals and ironstones. The division, however, which has yielded the greatest number of genera and species is that of the lower limestone and its accompanying shales, chiefly of marine origin. In the strata, believed to be of lacustrine or fresh-water origin from their fossil evidence, and from the absence of characteristic marine remains, as in the case of those strata which compose the lower and upper divisions of our coal and ironstone series, there are found certain forms of a small group of Ostracoda highly characteristic of these so-termed lacustrine conditions, and some of the species of which are found to range in time from the lower to the higher beds. The Ostracoda, wherever they appear, have evidently been very abundant in the waters in which these strata were being deposited, as their minute shells are often seen to have largely contributed to the formation of the beds. As a general rule they are hardly ever found mingling with the characteristic marine forms, which shows that the conditions under which the two groups lived were different.

Should any member of the Society who is forming a collection of Carboniferous fossils desire to add the Ostracoda he will find the methods of collecting and mounting them fully given in a paper which I read to the Edinburgh Geological Society in 1880 and printed in their *Transactions* (vol. iii., p. 290).

Very few fossiliferous localities which are found to contain either lacustrine or marine beds have not yielded some of the forms noted in the list appended to the present paper, but, of course, such forms are not found everywhere equally distributed. One that may be abundant or moderately common in one locality, may be rare or altogether absent in another, while some species, so far as yet known, are confined to one particular stratum in one locality. In spite of all the work which has up to this time been done amongst our strata, I believe there are still other forms to be discovered either in beds which have already been well searched, or in new localities and horizons of strata.

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In one of the papers by Messrs. Jones and Kirkby already referred to, there are two tables, No. 1 showing the stratigraphical distribution of the Carboniferous Ostracoda in Scotland and the North of England, and No. 2 giving the genera and species and their occurrence, so far as found, in the Carboniferous strata of England, Scotland, and Ireland. The second table is of great interest as it shows not only the occurrence but the apparent disappearance of many of the species, as the group is traced over the Carboniferous areas of Great Britain and Ireland. As previously stated, Western Scotland is credited with 107 species, Eastern Scotland with 70 species. Of this number 6 are not included in the list from the West, but the total for Scotland, East and West, is 116 species. England, North and South, has a total of 110 species, of which 4 are given as of doubtful occurrence. Ireland has yielded only 46 species, 2 of which are doubtful. The total for Great Britain and Ireland is therefore 182 species, including varieties, allocated amongst 34 genera and sub-genera. Of the 110 species recorded from England, 41 have not yet been found in Scotland, and of the 46 species found in Ireland 21 are absent from Scotland. On the other hand, when the list from Scotland is compared with the English and Irish ones we find that of Scottish species 51 are absent from England and 92 from Ireland, while of the 46 species from Ireland only 16 are present in English and Scottish strata.

I have no doubt that further research amongst the Carboniferous strata of Great Britain will discover many of the Ostracoda at present unrecorded from the several areas noted, but the general evidence, as presently known, so far as Table II. shows, is that many of the species were limited by physical conditions existing at the time they lived to certain areas of the sea and old lake bottoms, and probably by the varying temperature of the waters and other conditions under which this group of organisms existed.

I shall now shortly summarise the genera of Carboniferous Ostracoda found in Western Scotland, commencing with the larger forms in the order of Table II. of Messrs. Jones' and Kirkby's paper. Most of these larger forms have been found chiefly in the beds of the purer marine limestones, such as those formerly worked in the Bathgate quarries, at Braidwood, Carluke, and at Trearne,

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Beith, one horizon in the quarry at the Beith locality having yielded the greatest number and variety yet obtained. The same mode of occurrence seems also to hold good with those found in England and Ireland, the greater number of the larger forms being chiefly derived from the limestones.

Cypridina.—This genus is represented in the Carboniferous strata of Great Britain and Ireland by 13 species, 10 from Western Scotland, and all, with the exception of 2, from the limestone, these 2 being *C. primæva*, M'Coy, and *C. radiata*, Jones, Kirkby, and Brady. From one large fish coprolite from the limestone strata of Braidwood Gill, Carluke, which was sent me by the late Dr. Rankin, Carluke, in 1865, I extracted over 300 specimens of the shell of *C. primæva* with the valves united. This is a rare form elsewhere. *C. radiata* is found in shale in connection with the Airdrie blackband ironstone of our Upper Coal measures, and is also rare. I am inclined to add one other form of *Cypridina* not previously recorded in our list. This is a moderately large, oblong, oval species, one example of which I have found in the Trearne limestone, and which I provisionally place with the *C. oblonga*, J., K., and B., as found in the Irish limestone.

Cypridinella is represented by 7 species, of which 3 are found in the limestone of Beith and Bathgate. One of these, *C. Cummingii*, J., K., and B., is not recorded in the list of Messrs. Jones and Kirkby, but I have found a few examples in the Trearne limestone.

Cypridellina.—This genus is represented by 10 species, including varieties, of which only one species, *C. intermedia*, J., K., and B., has been noted from Scotland, but there in both the Eastern and Western districts. Of the other 9 species 7 have been found in Ireland and 2 in England.

Cypridella is represented by 6 species, 5 of which are found in our Western strata, 4 from the lower and 1 from the upper limestone. This genus has not yet been recorded from any of the English localities, but 5 of the species are found in Ireland.

Cyprella.—Of this genus 3 species are recorded, all from Scotland, only 1 of them being from our Western beds. They are all found in England, and 2 of them in Ireland.

Bradycinetus.—This rare form is represented by only 1 species, *B. Rankinianus*, J. and K., one or two examples of which were dis-

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covered by the late Dr. Rankin in small ironstone nodules from the limestone of the Gare beds, Carluke, the only place where it has yet been discovered. Dr. Rankin's type specimen is in the Hunterian Museum.

Entomoconchus is represented in Great Britain and Ireland by 3 species, 2 of which are found in the Trearne limestone of the Beith district. This genus is the largest form amongst Carboniferous Ostracoda yet obtained from British strata. Some of the examples from the Irish limestone exceed in size those found in Scotland.

Polycope.—This genus is represented by 3 species, 2 found in Western Scottish beds. These have been obtained from shales and small ironstone nodules found on the horizon of the Hosie limestone in the lower limestone series at Campsie, Carluke, and Busby.

Entomis is represented by 4 species, only one of which, *E. biconcentrica*, found by Dr. J. R. S. Hunter, in the Braidwood limestone, Carluke, is known in Scotland. The same species is the only one of the genus yet found in Ireland. The other 3 species were found in the North of England limestones.

Cytherella.—Of this genus, 19 species, including varieties, are recorded; but 3 of these are doubtfully referred to the genus. From Western Scotland 15 species are noted, being found in marine strata, which extend from the Calciferous sandstone series up to the strata of the upper limestones. Several of the species, however, are restricted to certain horizons and localities.

Leperditia.—In this genus 16 species are recorded from Britain and Ireland, 9 being found in the West of Scotland. The genus is chiefly marine in its mode of occurrence, but there are at least 2 species, *L. Scotoburdigalensis*, Hibbert, and *L. Youngiana*, J. and K., which seem to have inhabited brackish or lacustrine waters, in which characteristic marine organisms are absent.

Beyrichia, as now determined, holds a greater number of the species of Carboniferous Ostracoda than any of the other genera here noted, 20 species being recorded, of which no less than 15 are found in Western Scotland. With the exception of 2 species, the genus is essentially marine in its mode of occurrence, being found associated with all the fossiliferous limestones and shales. The 2 species excepted are *B. arcuata*, Bean, and *B. subarcuata*, Jones,

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the former being found in the lacustrine or fresh-water strata of the Upper Coal measures, and the latter in similar strata of the Calciferous sandstone series, and the middle coals and ironstones of the limestone series.

Beyrichiopsis.—Of this new genus 3 species are recorded, of which 2 are noted from the Calciferous sandstone series, in both Eastern and Western Scotland.

Kirkbya was first established by Professor Jones for a form found in the Permian strata of England. It is now found to be represented by 13 Carboniferous species, of which 10 are from Western Scotland. These are found both in the marine limestones and shales of the lower and upper limestone series, but certain of the species are confined to special localities and horizons.

Carbonia is represented by 10 species, 7 found in Western Scottish strata. This genus was established for the reception of certain forms belonging to a group highly characteristic of the lacustrine or fresh-water strata which alternate with the coal-beds both in Scotland and England, but which is seldom or never found associated with those Ostracoda essentially marine in their occurrence. It is not recorded from Irish Carboniferous strata, but will probably yet be found amongst its coal-beds.

Bythocypris is represented by 3 species, all noted from Eastern and Western Scotland, and found in the limestone and shales.

Argillæcia.—This is a genus at present represented by only 1 species, found in Eastern and Western Scotland and also in England. It is noted as of doubtful occurrence from Ireland.

Macrocypris is represented by 2 species, 1 rare and found as yet only at Millburn, Campsie. The other is noted from Eastern and Western Scotland—England and Ireland as doubtful.

Bairdia.—This genus is represented by 17 species, including 1 variety, and one form in which the genus is marked as doubtful. They are essentially marine in their mode of occurrence, and several of the species are plentiful, but some of the others are very rare. Of the 17 species recorded from Britain, 14 are found in Western Scotland, and only 1 is noted from Ireland.

Bythocythere is a genus which is represented by only two species, 1 found in Western Scottish strata, in the limestone shales at Brockley, Douglas coalfield, where it is rare. The other species is from England.

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Cythere(?) is represented by 10 species, but the genus is marked as of doubtful occurrence in the Carboniferous strata of Britain, and the species recorded in the list of Messrs. Jones and Kirkby are there placed only provisionally with *Cythere (?)* until further investigation is made. With regard to the species, they seem all to be good persistent forms. Of the 10 noted 3 are recorded from Western Scottish beds, but I am inclined to identify a form found in the Calciferous sandstone strata, from the coast near Heads of Ayr, with that of *C. (?) superba*, J. and K., this species being found in similar strata in Eastern Scotland.

Youngia.—This is the last genus on the list, and at present only 1 species is known. It was discovered by me in the limestone shales at Robroyston, north-east of Glasgow, in 1872, the only locality where it has yet been obtained. The form is very minute, but it is moderately common in the shale. Its chief characteristic, in which it differs from that of the other Ostracoda here noted, is "its toothed hingement, which is certainly unique among the Carboniferous Entomostraca, though partially represented in *Cytheridea* among later forms." This hingement is something like that seen in shells of the genus *Arca*.

In conclusion, I am inclined to think that as further investigations go on amongst the Carboniferous Ostracoda a better knowledge will be gained regarding several of the genera, in which some of the species are now placed, so that the present list must be so far looked upon as only provisional. This desirable end can be much helped in many cases by the discovery of better-preserved specimens of some of the forms than those yet obtained, as it is only the external forms and surface-markings of the fossil Ostracoda that those palæontologists who have taken up the group for investigation have had to work upon. In many cases it may yet be found that where palæozoic forms have provisionally been placed with recent genera, the discovery of any new characters in finer specimens of the older forms may lead to a change in the present arrangement and to the creation of new genera for their reception.

Having always taken a deep interest in the collection of the Microzoa or smaller organisms found in the Carboniferous strata of the Western Scottish coalfields, I cannot let this opportunity pass without mentioning the names of the other members of this

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Society, who, along with myself, have had the privilege of assisting Messrs. Jones and Kirkby with specimens for investigation, and upon which their list of Western Scottish Carboniferous Ostracoda has been built up. These are—Messrs. James Armstrong, James Bennie, Robert Craig, Dr. J. R. S. Hunter, David Robertson, John Smith, James Thomson, the late Dr. D. Rankin, and the late Dr. William Grossart. Nearly all of these names are mentioned again and again in Messrs. Jones and Kirkby's papers, and are honoured as discoverers by having certain new species named after them.

LIST OF PAPERS AND MONOGRAPHS BY MESSRS. JONES, KIRKBY, AND BRADY, ON THE CARBONIFEROUS OSTRACODA OF THE BRITISH ISLES, WHICH CONTAIN REFERENCES TO GENERA AND SPECIES FOUND IN SCOTLAND.

1. "Notes on the Palæozoic Bivalved Entomostraca—Münster's Species from the Carboniferous Limestone."—*Ann. and Mag. Nat. Hist.*, May, 1865.

2. "Notes on the Palæozoic Bivalved Entomostraca—Some Carboniferous Species."—*Ann. and Mag. Nat. Hist.*, July, 1866.

3. "On some Bivalved Entomostraca, chiefly Cypridinidæ of the Carboniferous Formations."—*Quart. Jour. Geol. Soc.*, Lond., Aug., 1873.

4. "Notes on the Palæozoic Bivalved Entomostraca—some Carboniferous Ostracoda from Russia."—*Ann. and Mag. Nat. Hist.*, 1875.

5. "Notes on the Palæozoic Bivalved Entomostraca—Some Carboniferous Species belonging to the genus *Carbonia*, Jones."—*Ann. and Mag. Nat. Hist.*, July, 1879.

6. "Description of the Ostracodous genus *Bairdia*, M'Coy—From the Carboniferous strata of Great Britain."—*Quart. Jour. Geol. Soc.*, Lond., Nov., 1879.

7. "Notes on the Palæozoic Bivalved Entomostraca—On some Carboniferous Species of the Ostracodous genus *Kirkbya*, Jones."—*Ann. and Mag. Nat. Hist.*, March, 1885.

8. "Notes on the Carboniferous Ostracoda of the North-west of England."—*Geol. Mag.*, Lond., Dec., 1885.

9. "On some Fringed and other Ostracoda from the Carboniferous Series."—*Geol. Mag.*, Lond., Oct., 1886.

10. "Notes on the Palæozoic Bivalved Entomostraca—On some undescribed species of British Carboniferous Ostracoda."—*Ann. and Mag. Nat. Hist.*, Oct., 1886.

11. "Notes on the Distribution of the Ostracoda of the Carboniferous Formations of the British Isles."—*Quart. Jour. Geol. Soc.*, Lond., Nov., 1886.

12. "A list of the Genera and Species of Bivalved Entomostraca found in the Carboniferous Formations of Great Britain and Ireland."—*Proceedings of the Geologists' Association*, Lond., vol. ix., 1886.

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13. "On Carboniferous Ostracoda from the Gayton Boring, Northamptonshire."—*Geol. Mag.*, Lond., 1886.

14. "On the Ostracoda found in the Shales of the Upper Coal measures at Slade Lane near Manchester."—*Transactions Manchester Geol. Soc.*, 1890.

15. "A Monograph of the British Fossil Bivalved Entomostraca from the Carboniferous Formations—Part I. The Cypridinidæ and their Allies."—*Palæontographical Soc.*, Lond., 1874.

16. "Monograph, Part I., No. 2. The Cypridinidæ and their Allies."—*Palæontographical Soc.*, Lond., 1884.

LIST OF THE GENERA AND SPECIES OF OSTRACODA RECORDED IN THE PAPERS AND MONOGRAPHS OF MESSRS. JONES, KIRKBY, AND BRADY, AS FOUND IN THE SEVERAL DIVISIONS OF THE CARBONIFEROUS STRATA OF WESTERN SCOTLAND.	Calciferous Sandstone Series.	Lower Limestone Series.	Lower Coal and Ironstone Series.	Upper Limestone Series.	Upper Coal and Ironstone Series.
1. *Cypridina primæva*, M'Coy.		x		x	
2. ,, *radiata*, Jones, Kirkby and Brady					x
3. ,, *brevimentum*, J., K. and B.		x			
4. ,, *Youngiana*, J., K. and B.				x	
5. ,, *Hunteriana*, J., K. and B.		x			
6. ,, *oblonga*, J., K. and B.		x			
7. ,, *Grossartiana*, J. and K.				x	
8. ,, *Phillipsiana*, Jones.		x		x	
9. ,, *Thomsoniana*, J. and K.				x	
10. ,, *scoriacea*, J. and K.				x	
11. *Cypridinella Cummingii*, J., K. and B.		x			
12. ,, *superciliosa*, J., K. and B.		x			
13. ,, *vomer*, J., K. and B.		x			
14. *Cypridellina intermedia*, J., K. and B.		x			
15. *Cypridella Edwardsiana*, De Kon.				x	
,, var. *septentrionalis*, J., K. and B.		x			
16. ,, *Koninckii*, Jones.		x			
17. ,, *obsoleta*, J., K. and B.		x			
18. ,, *Wrightii*, J., K. and B.		x			
19. *Cyprella chrysalidea*, De Kon. var. *subannulata*, J., K. and B.		x			
20. *Bradycinetus Rankinianus*, J. and K.		x			
21. *Entomoconchus Scouleri*, M'Coy.		x			
22. ,, *globosus*, J., K. and B.		x			
23. *Polycope simplex*, J. and K.		x			
24. ,, *Youngiana*, J. and K.		x			
25. *Entomis biconcentrica*, Jones.		x			
26. *Cytherella inflata*, J. and K.		x			
27. ,, *simplex*, J. and K.		x			
28. ,, *valida*, J., K. and B.	x	x			
29. ,, *Bennici*, J., K. and B.	x			x	
30. ,, *recta*, J., K. and B.		x		x	
31. ,, *concinna*, J., K. and B.		x			
32. ,, *brevis*, J., K. and B.		x		x	
33. ,, *obliqua*, J., K. and B.				x	
34. ,, *æqualis*, J., K. and B.				x	

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LIST OF THE GENERA AND SPECIES OF OSTRACODA RECORDED IN THE PAPERS AND MONOGRAPHS OF MESSRS. JONES, KIRKBY, AND BRADY, AS FOUND IN THE SEVERAL DIVISIONS OF THE CARBONIFEROUS STRATA OF WESTERN SCOTLAND.	Calciferous Sandstone Series.	Lower Limestone Series.	Lower Coal and Ironstone Series.	Upper Limestone Series.	Upper Coal and Ironstone Series.
35. *Cytherella obesa*, J., K. and B.		x			
36. ,, *scrobiculata*, J., K. and B.		x		x	
37. ,, (?) *rotundata*, J., K. and B.		x			
38. ,, (?) *reticulosa*, J. and K.		x		x	
39. ,, *extuberata*, J. and K.	x				
40. ,, *attenuata*, J. and K.	x				
41. *Leperditia Okeni*, Münster.	x	x		x	
42. ,, *suborbiculata*, Münster.	x	x		x	
43. ,, *oblonga*, J. and K.		x			
44. ,, *subrecta*, Portlock.	x				
45. ,, *Scotoburdigalensis*, Hibbert.		x			
46. ,, *compressa*, J. and K.		x			
47. ,, *Youngiana*, J. and K.			x		
48. ,, *Armstrongiana*, J. and K.		x			
49. ,, *Bosquetiana*, J. and K.		x			
50. *Beyrichia arcuata*, Bean.					x
51. ,, *subarcuata*, Jones.	x		x		
52. ,, *fastigiata*, Jones.		x		x	
53. ,, *multiloba*, Jones.		x		x	
54. ,, *colliculus* (?), d'Eichwald.		x			
55. ,, *radiata*, J. and K.	x	x		x	
56. ,, *fodicata*, J. and K.				x	
57. ,, *tuberculospinosa*, J. and K.		x		x	
58. ,, *gigantea*, J., K. and B.	x				
59. ,, *Bradyana*, J. and K.		x			
60. ,, *ventricornis*, J. and K.		x		x	
61. ,, *bicœsa*, J. and K.				x	
62. ,, *bituberculata*, M'Coy.		x		x	
63. ,, *craterigera*, Brady.	x	x			
64. ,, *intermedia* (?), Jones and Holl.	x				
65. *Beyrichiopsis fimbriata*, J. and K.	x				
66. ,, *fortis*, J. and K.	x				
67. *Kirkbya Permiana*, Jones.		x		x	
68. ,, *umbonata*, d'Eichwald.	x	x			
69. ,, *oblonga*, J. and K.		x		x	
70. ,, *annectens*, J. and K.		x		x	
71. ,, *costata*, M'Coy.		x			
72. ,, *Scotica*, J. and K.		x		x	
73. ,, *plicata*, J. and K.		x			
74. ,, *spinosa*, J. and K.		x			
75. ,, *Urei*, Jones.		x		x	
76. ,, *rigida*, J. and K.				x	
77. *Carbonia fabulina*, J. and K.		x	x	x	x
78. ,, *Rankiniana*, J. and K.			x		x
79 ,, *subula*, J. and K.		x			
80. ,, *secans*, J. and K.		x			
81. ,, *pungens*, J. and K.		x			x
82. ,, *Bairdioides*, J. and K.		x			x

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LIST OF THE GENERA AND SPECIES OF OSTRACODA RECORDED IN THE PAPERS AND MONOGRAPHS OF MESSRS. JONES, KIRKBY, AND BRADY, AS FOUND IN THE SEVERAL DIVISIONS OF THE CARBONIFEROUS STRATA OF WESTERN SCOTLAND.	Calciferous Sandstone Series.	Lower Limestone Series.	Lower Coal and Ironstone Series.	Upper Limestone Series.	Upper Coal and Ironstone Series.
83. *Carbonia Wardiana*, J. and K.		x			
84. *Bythocypris bilobata*, Münster.	x	x			
,, *Phillipsiana*, Jones & Holl, *var.*					
85. ,, *carbonica*, J. and K.		x		x	
86. ,, *sublunata*, J. and K.	x				
87. ,, (?) *cuneola*, J. and K.	x	x		x	
88. ,, (?) *cornigera*, J. and K.	x	x		x	
89. *Argillæcia æqualis*, J. and K.	x				
90. *Macrocypris Jonesiana*, Kirkby.	x	x			
91. ,, *carbonica*, Brady.		x			
92. *Bairdia Hisingeri*, Münster.	x	x		x	
93. ,, *curta*, M'Coy.		x		x	
94. ,, *plebeia*, Reuss.	x	x		x	
95. ,, *ampla*, Reuss.	x	x		x	
96. ,, *submucronata*, J. and K.	x	x		x	
97. ,, *amputata*, Kirkby.	x	x			
98. ,, *subgracilis*, Geinitz.		x			
99. ,, *brevis*, J. and K.	x			x	
100. ,, *grandis*, J. and K.	x				
101. ,, *subelongata*, J. and K.	x			x	
102. ,, *siliquoides*, J. and K.				x	
103. ,, *præcisa*, J. and K.		x			
104. ,, (?) *circumcisa*, J. and K.		x			
105. ,, *legumen*, J. and K.		x			
106. *Bythocythere Youngiana*, J. and K.		x			
107. *Cythere* (?) *superba*, J. and K.	x				
108. ,, (?) *intermedia*, Münster.	x	x			
109. *Youngia rectidorsalis*, J. and K.				x	

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No. XXV.—Notes on a small group of Carboniferous Foraminifera found in the Lower Limestone Shales of the Muirkirk District in Ayrshire, with a List of the Genera and Species found in the Coalfields of Western Scotland. By John Young, F.G.S., *V.P.*

[Read 9th April, 1891.]

The Foraminiferal group of organisms, recent and fossil, have always afforded an interesting branch of investigation to those persons who have taken it up, either for examination and study under the microscope, or for the purpose of forming a collection. This interest is much increased by the varied and beautiful forms of many of the shells when viewed externally, as also by the internal structure of the organisms when examined in transparent section under the microscope. In exhibiting to the Society this evening a series of sections and mounted specimens of Scottish Carboniferous Foraminifera from the marine limestone strata of our coalfields, I shall shortly refer, in the first place, to their mode of occurrence in the strata. In doing this I may state that they are found in nearly all the fossiliferous marine limestones and shales, but they are not always equally abundant, certain forms being often restricted to special horizons of strata and to particular localities.

When a search was first made in our limestone strata for this group of organisms by members of this Society, their attention was directed to the weathered limestones and shales in which many other forms of Microzoa, or minute life, of the limestone period had already been found. After having been carefully washed and searched, these rocks yielded on examination upwards of 30 species of Foraminifera, and I may state that, with the exception of *Saccammina Carteri*, Brady, found in the limestone, all the other forms were obtained in single specimens picked from the limestones and shales.

It is only comparatively recently that attempts have been made to grind thin transparent sections of our limestones and harder shales, which are suspected to contain Foraminifera, as by this method they are found *in situ* in the matrix in which they had been entombed. By following this plan many interesting sections have now been obtained, and to some of these I will shortly refer

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later on. In the meantime it may be stated that when the late Dr. H. B. Brady, F.R.S., commenced his valuable and interesting Monograph on the British Carboniferous Foraminifera, printed by the Palæontographical Society in 1876, nearly all the genera and species submitted for his determination, and whose structures he had to work out, figure, and describe, were sent as single specimens free from the matrix, and seldom showing more than surface characters. Dr. Brady had often, therefore, to section some of these minute shells to transparency so as to obtain some knowledge of their shell-wall structure and of the arrangement of their chambers internally. These microscopical sections were not made, he tells us, without difficulty, owing to the smallness of the bodies; but this was amply repaid when it unfolded structures of such great interest, especially in their relations to other well-known types of Foraminifera. Had the same work now to be done, he would, in many cases, with the aid of the sections in existence, have been saved a great deal of labour, and he would have been delighted, I am sure, with the sight of many transparent sections of small Foraminifera which he never had the opportunity of sectioning.

To get a more correct knowledge of the structure and external characters of the fossil Foraminifera, they should always be examined by two methods, where that is possible. 1st. By the examination of their true external forms, and surface-markings, or other ornamentation, as seen on the most perfect examples of the shells. 2nd. By the examination of transparent sections of their shells, or of the rocks containing them, so as to inspect thoroughly the structure of the shell-walls, and the form of the chambers, where such exist. It is, however, not always easy to find material which will permit of both methods of investigation, and collectors have, of course, to take the rocks containing Foraminifera just as they are locally found. If they are in a weathered condition, and only fit to search after washing, unweathered specimens hard enough for grinding should be searched for, and in this way both methods of investigation may be carried out.

Foraminifera are found, as I have already stated, in nearly all the fossiliferous marine limestones and shales of both the lower and upper groups of the limestone series in Western Scotland. Indeed, there are few transparent sections of these rocks in which

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examples of some of the forms may not be detected under the microscope by the practised eye. In some sections they are seen to be moderately common, and represent various genera and species; but the richest rock which I have yet examined from Western Scotland is a fine-grained limestone shale from the Muirkirk district of Ayrshire, found in connection with, or attached to, masses of the Carboniferous coral, *Chætetes septosus*, Fleming.

In order to obtain as full a knowledge as possible of the number and varied forms of the species present in this shale, I have ground to a thin transparency upwards of thirty sections, and for specimens of the coral with the shale attached, I am indebted to Dr. J. R. S. Hunter, Daleville, Carluke, and to Dr. David Forsyth, of Leeds, both members of this Society. The specimens were respectively from Durnhunch quarry, and Ashawburn, Muirkirk, and it is interesting to note that there is some difference in the distribution and abundance of the Foraminifera present in the two localities. Thus in the shale from Ashawburn, *Archædiscus Karreri*, Brady, is the most abundant and characteristic Foraminifer present, and it may be counted by the dozen in most sections. Along with it are examples of other genera, such as *Endothyra*, *Stacheia*, *Trochammina*, and *Valvulina*, each being represented by one or more species. In the sections of this shale, there is also to be seen, under the microscope, numerous minute yellowish-brown crystals of a rhombohedral shape, each having a darker-coloured centre than its outer walls. They are so abundant that many of the sections are seen to be crowded with them, the rock being thus, in a measure, characterised by their presence. I cannot yet say what is their mineral composition, but it may be either dolomite or siderite, or a combination of these with calcite. In no other sections of Carboniferous shale have I yet met with similar crystals.

In the sections of the shale from Durnhunch quarry these small crystals are absent, but there is a greater variety of the Foraminifera. *Archædiscus*, so plentiful in the former locality, is here somewhat rare, and its place is taken by *Endothyra* and *Textularia*, each being represented by several characteristic forms. Other genera represented are *Climacammina*, *Trochammina*, *Stacheia*, and *Valvulina*. The species belonging to the several genera from this Muirkirk shale will be found in the list given at the end of this paper.

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Besides the Foraminifera, the Durnhunch shale contains examples of that curious organism first found in the Silurian rocks of the Girvan district, and named *Girvanella* by Prof. H. Alleyne Nicholson and R. Etheridge, jun., in their "Monograph on the Silurian Fossils of the Girvan district," p. 23, where it is placed with the Foraminifera. In my sections of the Muirkirk shale there are at least two varieties, one having much more minute tubes than the other; both are found in the shale in the form of small twisted bundles. There are also seen in the sections fragments of larger tubes having moderately thick walls, and with the same structure as that of the other arenaceous Foraminifera present. These tubes in longitudinal section are seen to taper gradually to one end, but are not chambered within. They may therefore belong to an uncoiled form of *Trochammina*, like that of *T. filum*, Schmid, figured and described by Dr. Brady from the Permian formation. This form consists, he states, "of a long tube of gradually increasing diameter, irregularly bent, and often partially coiled at its commencement." Should my conjecture prove correct, it will add another species of *Trochammina* to our Scottish Carboniferous list.

I have only further to remark respecting the Muirkirk Foraminifera, that all the forms are exceptionally well-preserved as regards their internal structure; in fact they are in better condition than those found in our purer limestones, which have, in many cases, lost much of their finer structure through crystallization of the limestone. I may also add, regarding my sections of limestone shale, that Foraminifera are not the only organisms they contain. Scattered throughout the sections there are the remains of Ostracoda, with fragments of various species of Polyzoa, Corals, Crinoids, Brachiopods, univalve and bivalve shells, and sometimes small teeth and scales of fish. We have, therefore, in this shale, all the preservable finer organic débris of a portion of an old sea-bottom of the lower Carboniferous limestone period, the fragments being wonderfully well-preserved when we consider the great antiquity of the rocks in which they are found.

Postscript.—Since the period when the foregoing paper was read to the Society I have been giving some attention to another Foraminiferal form found somewhat plentifully in one of the

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limestone shales at Muirkirk, and less abundantly in a few of the other Carboniferous limestones of Western Scotland, and which is neither figured nor described in Dr. Brady's Monograph. This form is found to consist of small, evenly rounded spheres, and sections of spheres, of various shapes and sizes, showing clear evidence of having once been clustered together, as in the recent Globigerinidæ. When thin transparent sections of these spheres and their segments were examined under the microscope, and compared with similar sections of a deep-sea *Globigerina* ooze, which I have prepared, they were seen to be very much alike both as to size and form, as well as in the thickness and structure of their shell-walls. The only point of seeming difference is, that in the Carboniferous form the various segments which formed the clusters are now in a more broken-up and scattered condition in the surrounding sediments than is seen in the clusters from the deep-sea deposit. Separated segments of the latter are, however, seen in the sections from the recent deposits, with exactly similar appearances to those found in our limestone strata.

The Carboniferous form may be briefly described as consisting of complete spheres, which appear as perfect circles in the sections when they happen to be cut transversely along certain lines. They are also seen as segments of spheres of varying size and form which show, on one edge, where they were attached to other spheres or segments of the clusters of which they once formed part. These circles and segments are seen to be uniformly thin-walled, and generally show a dense, sub-arenaceous shell-structure when looked at under the microscope by transmitted light. From these characteristics they are easily distinguished from any of the other Foraminifera, which are thicker walled as well as different in form. The spheres and segments are often filled with a clear, structureless calcite; when this is not the case their inner walls are coated with some mineral deposit, or filled with the sediment which formed the rock matrix.

Dr. Brady, in his Monograph, makes no reference to *Globigerina* as being found in Carboniferous limestone strata, but states that *Textularia*, and one or two other forms found in the same strata, are now placed in the Globigerinidæ group, as they apparently possess the same kind of shell-structure, though they differ in

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form from the recent *Globigerina*. So far, therefore, as form and other characters go, I am inclined to place this Carboniferous form provisionally in my list with *Globigerina*, as that genus, so far as known to me, is the only one which possesses characters which agree most closely with the new form. I leave its relationship to recent and living species for future determination.

In concluding, I have only further to remark that this interesting Carboniferous representative of a deep-sea Foraminifer which is still living in our seas is always associated in the limestones with other species of the group, some of which are also allied to recent living genera. The following are a few of the chief localities in which it is found, viz., Durnhunch quarry, Muirkirk, in the limestone shale; Trearne and Dockra, Beith, in the limestone; Baidland and Law quarries, Dalry, in the limestone; Campsie, in the main limestone, where it is found with *Saccammina*, a form still living. I have also found it moderately common in sections of the limestone from Closeburn quarry, Dumfriesshire, the strata there belonging to the Calciferous sandstone series of the lower Carboniferous formation.

Species from Muirkirk Shale.	LIST OF CARBONIFEROUS FORAMINIFERA FROM WESTERN SCOTLAND.	Lower Limestone Series.	Upper Limestone Series.	LIST OF CHIEF LOCALITIES WHERE SPECIMENS HAVE BEEN FOUND.
	Saccammina Carteri, Brady.	x		Braidwood, Carluke. Campsie main limestone.
*	*Climacammina antiqua*, Brady.			Brockley. Muirkirk.
*	*Trochammina incerta*, (d'Orbigny).	x	x	Robroyston. Muirkirk.
*	,, *centrifuga*, Brady.	x	x	Robroyston. Muirkirk.
	,, *annularis*, Brady.	x		Capelrig, Kilbride.
	,, *gordialis*, P. and J.	x		South Shiells, Kilbride.
	,, *pusilla*, (Geinitz).	x	x	Trearne, Beith. Gare, Carluke.
	,, *Robertsoni*, Brady.		x	Gare, Carluke.
*	*Valvulina palæotrochus*, Ehrenberg.	x	x	Robroyston. Brockley. Muirkirk.
*	,, ,, var. *compressa*, Brady.	x	x	Gare, Carluke. Brockley, Muirkirk.
*	,, *Youngi*, Brady.	x		Brockley. Trearne. Dalry. Muirkirk. Campsie.
	,, ,, var. *contraria*, Brady.	x		Brockley. Trearne. Beith.

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Species from Muirkirk Shale.	LIST OF CARBONIFEROUS FORAMINIFERA FROM WESTERN SCOTLAND.	Lower Limestone Series.	Upper Limestone Series.	LIST OF CHIEF LOCALITIES WHERE SPECIMENS HAVE BEEN FOUND.
*	*Valvulina decurrens*, Brady.	x	x	Gare, Carluke. Brockley, Muirkirk.
	,, *plicata*, Brady.	x		Calderside, Blantyre. Hairmyres.
	,, *rudis*, Brady.	x		Headsmuir, Carluke.
*	*Endothyra Bowmanni*, Phillips.	x	x	Calderside. Trearne. Dalry. Muirkirk.
*	,, *ammonoides*, Brady.	x	x	Gare, Gillfoot, Carluke. Muirkirk.
*	,, *globolus*, (d'Eichw).	x	x	Gillfoot. Braidwood. Muirkirk.
*	,, *crassa*, Brady.	x	x	Brockley. Muirkirk.
*	,, *radiata*, Brady.	x	x	Robroyston. Gillfoot. Brockley. Muirkirk.
*	,, *macella*, Brady.	x		Brockley. Muirkirk.
*	,, *ornata*, Brady.	x		Brockley. Muirkirk.
	,, ,, var. *tenuis*, Brady.		x	Robroyston. Barmulloch.
	,, *subtilissima*, Brady.	x		Brockley.
	Nodosinella concinna, Brady.		x	Belston Burn, Carluke.
	Stacheia marginulinoides, Brady.	x		Brockley.
	,, *fusiformis*, Brady.	x		Belston Burn. Brockley.
	,, *pupoides*, Brady.	x		Brockley. Hairmyres.
	,, *acervalis*, Brady.	x		Hairmyres. Gare, Carluke.
	,, *congesta*, Brady.	x	x	Belston Burn. Carluke.
*	,, *polytrematoides*, Brady.	x	x	Gare. Braidwood. Hairmyres. Muirkirk.
	Lagena Parkeriana, Brady.		x	Belston Burn, Carluke.
	,, *Howchiniana*, Brady.		x	Belston Burn, Carluke.
*	*Textularia gibbosa*, (d'Orbigny).	x		Brockley. Muirkirk.
*	,, *eximia*, (d'Eichw).	x		Brockley. Muirkirk.
*	,, (undetermined species).			Muirkirk.
	Bigenerina patula.	x		Headsmuir, Carluke.
*	*Archædiscus Karreri*, Brady.	x	x	Craigenglen. Brockley. Muirkirk. Belston Burn.
*	*Girvanella*, (sp.) (Nich. and Ether.).	x		Muirkirk. Law quarry, Dalry.
	Haplophragmium rectum (?) Brady.	x		Hillhead quarry, Beith.
*	*Globigerina*, (sp.)	x		Beith. Campsie. Dalry. Muirkirk.

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No. XXVI.—Note on a "Wash-out" in a Shallow Pit of the Drumshangie Coal Company, near Airdrie. By Robert Dunlop.

[Read 9th April, 1891.]

Two miles from Airdrie, and in a north-easterly direction, the minerals are at present being wrought by the Drumshangie Coal Company. In the month of November, 1890, they put down a shallow pit, 36 feet deep. At a depth of 33 feet from the surface the Upper Drumgray coal, 12 inches thick, was met with.

On examination, the coal was found to be badly burned and very sulphurous, but in the hope that it would improve in quality and in thickness a mine was driven into it. To the surprise of the miners the metals disappeared, and in their place were found rounded stones, having the appearance of being thoroughly water worn, and of all sizes, ranging from many hundredweights downwards. They consisted of sandstone, ironstone, faikes, shale, coal, gas coal, and in fact representatives of nearly almost all the ordinary carboniferous rocks known in the district. There were also a few strangers found amongst the boulders, and specimens of these are laid on the table.

A most interesting point in this section is that the material between the rounded stones is not the ordinary Boulder-clay but a very pure fire-clay, which, however, became more gravelly and sandy at the bottom. After the rounded stones had been washed by the rain and weathered, I went back, and for some hours examined all the smoothed stones to see if I could detect any scratches, but I could see none. In ordinary Boulder-clay there is no difficulty in finding any number of striated stones. Another point which may be noted, and of which I have never known a previous occurrence, was the presence of fire-damp in the Boulder-clay, and to such an extent that the men had to work with safety lamps. This is the more remarkable, as in the coal seam, and indeed in all the seams wrought by the Drumshangie Coal Company in the neighbourhood, fire-damp is practically unknown.

I have thought it best to bring these particulars before the Society to-night, believing it is right to put all such phenomena on record, so that they may be available if required at some future date. The collection of such points may one day help to explain various matters now imperfectly understood.

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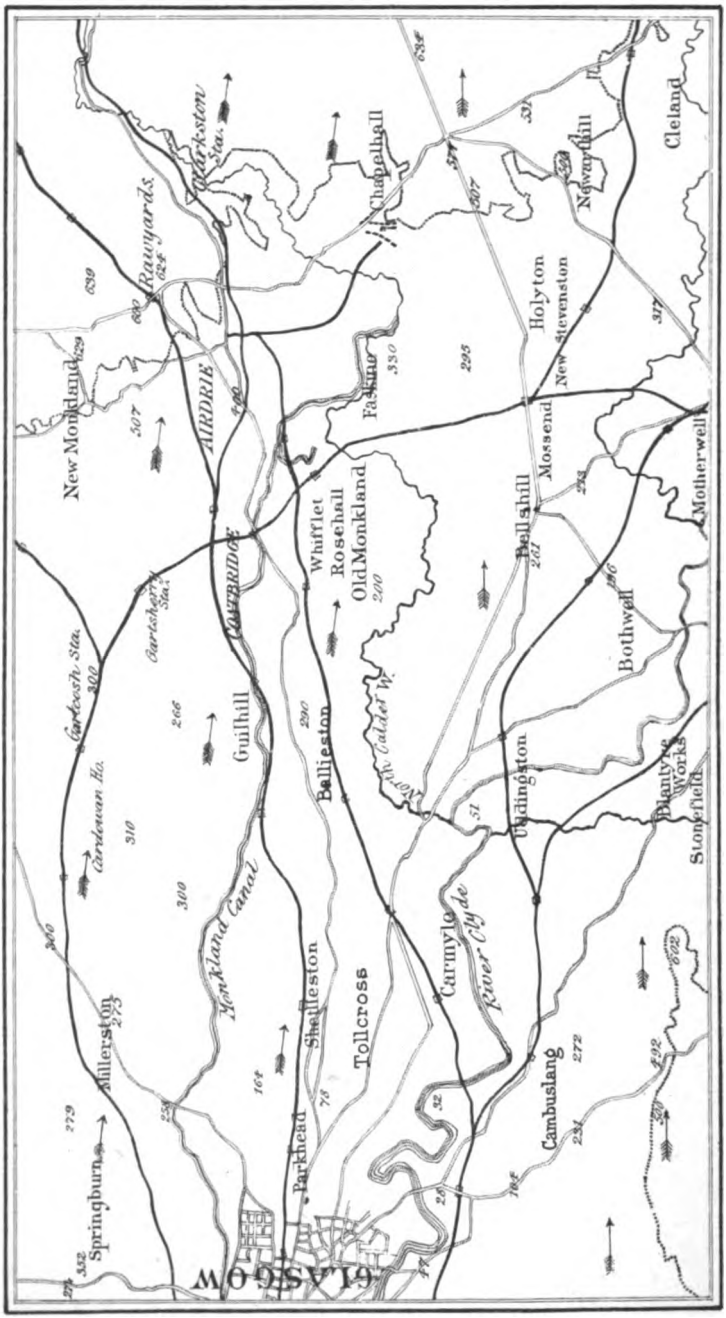

SKETCH MAP OF DISTRICT, GLASGOW TO CHAPELHALL.

Figures indicate feet above sea-level. Dotted line = 500 feet. Arrows indicate direction of ice-flow.

CARTER & PRATT, LITH.

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No. XXVII.—On the Alleged Proofs of Submergence in Scotland during the Glacial Epoch.—I. Chapelhall, near Airdrie. By Dugald Bell, F.G.S. With a Map.

[Read 10th March, 1892.]

One of the most interesting questions in recent geology relates to the degree of submergence which took place in Britain during the Glacial epoch. That some submergence did occur is admitted, and seems clearly proved; but *how much*, has been matter of prolonged discussion and difference of opinion among geologists. Till recently, a submergence of from 1500 to 2000 feet was freely affirmed, with regard to parts, at least, of the British Isles. This affirmation rested on certain "high-level shelly gravels" found in Wales and on the borders of Wales, and on one or two Irish mountains. It was assumed, of course, that these shelly gravels, as well as similar gravels without shells extending several hundred feet higher, had all been deposited at these heights by the sea. Gradually, however, this conclusion came to be doubted. First, the shell-less gravels were discarded as devoid of proof—the mere fact of their being gravels, more or less evenly stratified, being far from conclusive as to their being laid down by the sea. The shelly gravels themselves were next called in question, and were found to present so many doubtful features—in their detached and sporadic character, in their being largely made up of far-travelled and striated materials, and in the mixed and broken nature of their shelly contents—that the conviction grew up that they were not really in place, but had been transported somehow, probably by ice, from a former bed of the sea at a lower level. As similar instances of the transport of marine organisms by ice became known in increasing numbers this conviction strengthened, and it was corroborated by observations on the glaciation of the surrounding neighbourhood and of the country generally, as well as by comparison with what is known regarding the glaciation of other parts of the northern hemisphere. The researches and observations of Belt, Goodchild, Clement Reid, Carvill Lewis, and others,* have tended powerfully to establish the conclusion that these "high-level shelly drifts" are really of glacial origin,

* *Nature*, May, 1874; *Geol. Mag.*, 1874, p. 496; *Ib.*, 1881, p. 235; *Reports, Brit. Assoc.*, 1886-87; *Transactions*, vol. ix., part 1, p. 100.

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so far as their present position is concerned. Hardly any geologist of mark now stands up for this "great submergence." Here and there, it is true, some doughty champion, unaware apparently that the position has been abandoned, steps bravely forward to defend it. But, speaking generally, we may say that this "great submergence" is a day-dream of the past, and "lives no longer in the faith of reason."

But there are other degrees of submergence—minor, yet very considerable—usually admitted and taught by geologists, which we still venture to think are far from being satisfactorily proved.

The first of these is the submergence of between 500 and 600 feet supposed to be indicated by a bed of shelly clay recorded to have been found at Chapelhall, near Airdrie, about 11 miles east of Glasgow. There is certainly a great difference between a submergence of 1360 and one of 526 feet; and it is quite possible there may be good reasons for doubting or disbelieving in the one which do not apply to the other. But it appears to us that even this second or much smaller submergence is by no means clearly made out.

I. *Accounts imperfect and doubtful.*—Our first remark on this instance at Chapelhall is that very little is really known of it—far too little to found so much upon it as has been done. May we ask attention to a brief narrative of what has been recorded regarding it?

(A) This "deposit" was first brought into notice by Mr. Smith of Jordanhill, in a paper read to the Geological Society in 1850, and re-published in his well-known little volume of "Researches in Newer Pliocene and Post-Tertiary Geology," in 1862. "The shells," Mr. Smith states, "were discovered by Mr. James Russell, an operative miner, in digging a well." Mr. Russell informed Mr. Smith that "at the depth of 14 feet from the surface he came to a bed of brick clay containing the shells." The surface of the ground here Mr. Smith found to be 524 feet, and, therefore, the shelly clay was 510 feet above the sea. At the time of his visit Mr. Smith saw part of the "superincumbent matter which had been thrown out, lying at the mouth of the well;" and this, he says, was "unquestionably true till," and contained, among other stones, "a small granite boulder," which must have been brought from a distance of about 60 miles to the N.W. He adds, "Mr.

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Russell states that after passing through the shelly bed of brick clay he came again to the till"; proving that there had been "more than one deposition of the till or Boulder-clay."

It does not appear, then, that Mr. Smith either saw the shelly clay or took the shells from it himself; the latter he seems to have got either from Mr. Russell, or from Mr. John Craig, a mining engineer, whom Mr. Russell had first seen, and who informed Mr. Smith of the "deposit," and accompanied him to the locality. These shells—their number is not stated—seem all to have been of one species, *Tellina calcarea* (or *T. proxima*)—"an Arctic species," remarks Mr. Smith, "extremely abundant in the Clyde Pleistocene beds." The deposit was accordingly described by Mr. Smith as "a bed of the *Tellina*."

This is really all that can be gathered from Mr. Smith's paper. It rests throughout on the authority of Mr. Russell.*

(B) Sir Archibald Geikie, in the preparation of his valuable Memoir on "The Phenomena of the Glacial Drift of Scotland," † visited the spot, also under Mr. Russell's guidance. He describes it as situated "on the crest of a ridge which, rising high above the surrounding country, commands an extensive view across the lower part of the basin of the Clyde. On the water-shed of this high-lying ridge a well was sunk some years ago, and while the excavations were in progress the shells were found." Sir A. Geikie then gives particulars corresponding with those stated by Mr. Smith, adding that the lower till was here "about 24 feet thick, and lay directly on the Carboniferous strata of the district. The brick clay, at its thickest part," he continues, "measured 2 feet 1 inch in depth, but thinned away rapidly on every side so as to allow the

* "Researches," pp. 139-142. Of course in our remarks we do not wish to cast the slightest doubt on Mr. Russell's testimony as to the fact of the shells being found where he stated; all we say is that he does not seem to have examined the clay very minutely—certainly not with the care and minuteness now considered desirable, in view of the many questions which have arisen regarding these shelly clays; and that, so far as appears, neither Mr. Smith nor any other geologist had an opportunity of doing so personally. It is incredible that Mr. Smith, if he had seen the clay itself, should not have said so, and only mentioned the "superincumbent matter"; incredible also that, if he had had the opportunity, he should not have examined the clay for other organisms besides the *Tellina*, and stated that he had done so.

† *Transactions*, vol. i., part 2, 1863.

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upper and lower till to come together. From a number of additional wells, sunk on purpose, Mr. Russell ascertained that the clay lay in a hollow of the undermost till, and that this hollow measured about 19 feet long by about 5 feet broad. Pits which were dug beyond the boundary of this little trough showed a great depth of the usual till, but without a trace of brick clay. The shells," adds Sir Archibald, "consisted entirely, I believe, of *Tellina proxima.* Usually the specimens were broken, but a good many were taken out entire, with both valves together." *

Sir Archibald thus adds several particulars to Mr. Smith's account; but, excepting his observations on the surface, which are interesting and valuable, these particulars are still all derived from Mr. Russell. The well was built up; the clay was not visible; but all that could be learned regarding it confirmed its local and limited character.

(C) About the same time as Sir A. Geikie's visit, or apparently shortly before it (though their account was later in being published), Dr. Crosskey and the late Dr. Bryce visited the locality and made some observations, the results of which were communicated by Dr. Crosskey in a paper to the Geological Society in January, 1865. † Dr. Crosskey alluded to the perplexing nature of the deposit as occurring "intercalated between two masses of Boulder-clay," and his more immediate object was to examine "whether the superincumbent matter was without doubt the true till," as Mr. Smith had pronounced it to be. He thought it was not, but that the upper clay might have been "the wash from a ridge of true Boulder-clay which rises above it, and against the slope of which it rests." This view, however, seems to be untenable. But, leaving this in the meantime, we note that at Dr. Crosskey's and Dr. Bryce's suggestion Mr. Russell "sank a fresh well, 7 yards from the old one," the section in which was entirely different, and showed *no* shelly clay.

Old Well.		New Well.
Upper Boulder-clay, - -	14 ft., -	5 ft. 3 in.
Clay with Shells, - -	2 ft.	
Boulder-clay (thickness not stated), -		9 ft. 6 in. (not pierced through.)

We may take it that this well was sunk before Sir A. Geikie's

* *Op. cit.*, pp. 58-9.

† *Quarterly Journal of the Geological Society*, vol. xxi.

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visit; for, by that time, the information was that "a number of wells" had been sunk, and that the shelly clay had been ascertained to be "about 19 feet long by 5 broad." Of course, had this been known when Drs. Bryce and Crosskey were on the spot, there was no use in sinking a new well "7 yards from the old one."

The thickness of the lower Boulder-clay, also, which was quite indefinite at the time of Dr. Crosskey's visit, seems by the time of Sir A. Geikie's to have been ascertained to be "about 24 feet thick."

The only point on which Dr. Crosskey's account goes beyond either Mr. Smith's or Sir A. Geikie's, is in stating that besides the *Tellina calcarea*, "*Cyprina Islandica*, and a large *Balanus* are found in the clay." In one sense the occurrence or non-occurrence of these organisms in the clay is of no great consequence, as the *Tellina* by itself is sufficient to mark the deposit as glacial. But it is a curious point how, about fourteen years after Mr. Smith's account was first written, and a year or two after it was re-published in book form, these additions came to be made to the organic contents of the clay. The well does not appear to have been re-opened in the interval; none of the clay seems to have been retained for further examination; new wells were sunk in vain to find it again, and not one of the observers we have been quoting from states he ever saw it. Whence, then, came the *Cyprina Islandica* and the *Balanus*?*

* We understand Dr. Crosskey received the particulars given in his paper from Mr. Russell. How, then, was Mr. Russell able to say so much more about the clay to Dr. Crosskey than he had said to Mr. Smith? As already said, we make no imputation against Mr. Russell's good faith and general accuracy; but mistakes will sometimes happen; and it is, at least, a coincidence that Mr. Smith in his paper (which, at the date of Dr. Crosskey's visit, had lately been republished), a few lines after describing the Chapelhall till, goes on to speak of organic remains sometimes found in the till generally, and adds, "upon one occasion I found broken and water-worn fragments of shells irregularly dispersed in it, amongst which I recognised the massive hinge of *Cyprina Islandica*, and the stem of a large *Balanus*" ("Researches," p. 141). A hasty, or not very exact, or, for the moment, inattentive reader, might make the mistake of supposing that here Mr. Smith was still referring to the Chapelhall clay, instead of the till in general; though, of course, Mr. Russell would have less excuse than most men in making such a mistake, seeing it was he who first supplied Mr. Smith with his information. In whatsoever way these additions to the fauna of the Chapelhall clay came to be made, they are to be found repeated, generally on Dr. Crosskey's authority, by various writers down to the present time (see, for example, Dr. James Geikie's "Great Ice Age," p. 163).

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We have entered into these particulars simply to show how imperfect and unsatisfactory, in many respects, is all we know of this Chapelhall deposit.*

From our own observation we can corroborate Sir A. Geikie's description of the locality. The well is situated at the upper end of the village of Chapelhall, behind the cottage once occupied by Mr. Russell, who died about twelve years ago. Its position is on one of the highest of those long ridges of Boulder-clay which abound all over the district, extending approximately in a direction from N.W. to S.E., and it is not far from the summit of the ridge. It seems impossible, therefore, that the upper till could be a "wash down" from a higher ridge of "true Boulder-clay," as Dr. Crosskey suggested. Had it been in the hollow between two such ridges, this would have been more probable. But the fact is as stated, its position is high, on the very back or crest of the ridge, conspicuous all round; and there is not the slightest evidence of any "slip" of the Boulder-clay near the spot.

VIEW OF CHAPELHALL. × *Cottage with Well.*

But we need not dwell longer on this, seeing that the upper is generally acknowledged to be as true till or Boulder-clay as the lower.

At present the well is about 16 feet deep (it was originally 2 feet deeper, but has been filled in at the bottom); and, as might be expected from its situation, the supply of water is not very copious, and in a continuance of dry weather almost ceases, or falls very low. At such a season, if the well were run dry, an effort might be made to reach the "shelly clay" again, and bring

* In a note received lately from the veteran geologist, Mr. David Robertson, he says, "It is a remarkable fact that no other shells were found associated with the *Tellina* in the Chapelhall deposit. I have never found it without finding others with it, and often it was far outnumbered by other species."

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up a portion of it for further examination.* This is, of course, desirable, seeing that so little is known of it; that though mentioned in almost every geological work for the last forty years, it would seem that no geologist since Mr. Russell's day has set eyes upon it; and that though carefully searched for all round the neighbourhood—in railway cuttings, shafts, quarries, and other openings,—it has not been met with since Mr. Russell dug his well, and built it round, forty-two years ago.

II. *Difficulties in regard to it and other High-level Deposits.*—But even supposing the clay were found again in the same spot, however satisfactory this might be in some respects, it could hardly alter, or add to, the fact that here, at the very utmost, we have a limited patch or strip of shelly clay imbedded in the till or Boulder-clay at this height above the sea. The question then arises, Is this sufficient to sustain the immense pile of inferences that has been built upon it—first, a period of extreme glaciation, when "the great central valley of Scotland brimmed with glacier ice;" then a period of "milder conditions," and a submergence of the land to a depth of between 500 and 600 feet beneath its present level; then a re-elevation of the land, and "another mighty ice-sheet again overflowing it?"† Restricting ourselves at present to the submergence, we ask, Is this patch of shelly clay sufficient to prove a submergence of between 500 and 600 feet? Some have thought so. "Evidently," says one esteemed writer, "the shelly clay at that place marks an old sea-bottom, when the sea rose not less (indeed, certainly more) than 526 feet above its present level."‡ We venture to think it is not sufficient without further confirmatory evidence, which, if the conclusion were true, might reasonably be looked for, but of which there is a very striking lack and deficiency; also that, as in the case of Moel Tryfaen, the theory of a purely marine origin for the deposit entails more and greater difficulties than it solves.

(1) *Its Limited Extent.*—If this Chapelhall clay were in the true sense a shell-bed, marking the former level of the sea, might we not expect to find remains of it in many localities all over the district and neighbourhood, and in other parts of the country as well as here?

* We are in hopes of this being done.

† "Great Ice Age," pp. 175-6.

‡ *Ib.*, p. 175.

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Dr. J. Geikie justly points out that "when a free ocean flowed over the site of the district in question"—supposing it did so—"a very large part of the Scottish lowlands would be submerged. The sea would wash the base of the Kilsyth hills on the north, and towards the south would extend up the Clyde valley as far at least as Hazelbank, a few miles below Lanark."*

In short, the sea would rise to a considerable height along the Campsie and Kilsyth hills on the one hand, and the Ayrshire, Renfrewshire, and Lanarkshire hills on the other; as well as along every range of hills all over the kingdom, unless the submergence were restricted to this district, which is not maintained.

Now, if there was such a submergence, the reason commonly assigned for the paucity and disappearance of all traces of it is the "clearing out" effected by the "second" or subsequent glaciation. But, as we have tried to show elsewhere,† this is a most inadequate reason, and might account for the absence of such traces in a few localities, but not for their disappearance all over the country. There are special features in this district which make it extremely unlikely. These hills to which we have referred as bounding the midland valley are characterised by numerous bends and inlets, and are intersected by transverse valleys, in which marine deposits would be most likely to accumulate, and where they would most likely be preserved. As Dr. Geikie well states, when referring to the beds of sand and gravel—old stream-deposits—often found intercalated in the Boulder-clay, "During the glacial period, the ice-sheet which followed the lines of the principal valleys must frequently have crossed the lateral and subsidiary valleys nearly at right angles. In the main valleys the glacier would exert its full influence, but it would not be able to do so in the narrow lateral valleys and ravines; the ice and till would merely topple into the glens referred to and gradually choke them up, and the main mass of the glacier would then pass on over the whole. In such narrow glens, then, any silt, sand, or gravel that had gathered during the temporary absence of the ice-sheet would not be so likely to be ploughed out when the ice returned as the similar materials which had accumulated in those broader and more open valleys where the ice would have full freedom to move and exert its erosive power."‡

* *Op. cit.*, p. 175. † *Transactions*, vol. ix., part 1, p. 100.
‡ "Great Ice Age," pp. 133-4.

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Why, then, if there was a submergence to the extent alleged, are such high-level shell-beds not found in scores of the lateral glens, valleys, and ravines which were comparatively sheltered from "the erosive power of the old glaciers," and all evidence of such submergence left, not in a sheltered position, but in a most unlikely place—on the summit of a high exposed knoll or ridge "nearly in the centre of that broad tract of lowland country" which it is admitted was swept by the old glaciers, and formed one of their main pathways and outlets? That is one difficulty.

It may be objected that this is an argument from a negative, which is always inconclusive. But in one sense there is a positive element in it—in a part of the country so much cut up and dug into, if such traces have not been found, we may safely conclude it is because they are not there.

(2) *Absence of Marine Organisms in the Overlying Deposits.*—Another difficulty is, if the "second glaciation" ploughed up and removed the shell-beds formed during the submergence—as it must have done to a great extent—why do we not find remains of these scattered throughout the upper Boulder-clay? We have instances of this in the "shelly tills" that are found in various parts of the kingdom, and in other parts of the world—wherever the ice-sheet is known to have passed over what had been a sea-bottom.

When the prolonged period of submergence, during which the broad midland valley was an ocean sound, passed away, and the "mighty ice-sheet again overflowed the land," should we not find abundant traces of the sea incorporated with the overlying Boulder-clay, its latest work? "During the last cold period," says Dr. Geikie, "the confluent glaciers cleared out the marine deposits laid down in preceding interglacial times, and incorporated them with their *moraine profonde.* This is the origin of most [all?] of our shelly tills or Boulder-clays." *

Again, "We know that the latest ice-sheet which overflowed Scotland did enter the sea and mix up marine deposits with its moraine. Thus it was that the silt and shells lying on the bed of the Minch were pushed up over the north end of Lewis, and so also was it that Caithness received the spoils of the Moray Firth." † Why, then, is this "upper Boulder-clay" of Lanarkshire—the ice

* *Op. cit.*, p. 329. † *Ib.*, p. 390.

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forming which must have passed over miles and miles of former sea-bottom (if the alleged submergence were a fact)—why is it not charged with marine remains?

On this point we cannot do better than quote Dr. Geikie's own words, "While there is proof to show that immediately before the appearance of the last ice-sheet, Scotland was submerged to a depth of more than 500 feet, yet the upper Boulder-clay of that country rarely contains broken shells, save in maritime districts. Why, we may ask, does not the upper Boulder-clay of the Central Lowlands (a great proportion of which must have been submerged before the last ice-sheet overflowed Scotland) contain broken shells, and afford other indications of the latest confluent glaciers having occupied the bed of the sea?"

That is the question, as Dr. Geikie well puts it. What is the reply? "That is a very hard question to answer, and I fear we must wait some time yet for an adequate solution of the difficulty." * We think it will be admitted that this is not satisfactory. If we adopt a theory, and find that it lands us in an inexplicable difficulty, to say simply that "we must wait some time yet for a solution" is surely very unsatisfactory, and should lead us at least to re-examine the theory, or inquire whether we are really shut up to its adoption.

(3) *Highly Arctic character of Shells found in the Clay.*—Another difficulty presents itself. It has been supposed that these shells were deposited in a "mild interglacial period"—in one of such periods when "the great ice-sheet disappeared from the low grounds and shrank into a series of local glaciers among the mountain regions;" nay, "which there is no evidence to show might not have been warm enough at times to cause all the ice and snow to disappear from the country." † Dr. Geikie, for example, dwells on this point, impressing upon the minds of his readers the long periods implied in such great climatic changes, and stating that it seems "not unreasonable to infer that the comparatively mild and genial periods, of which the interglacial beds are memorials, may have endured as long as these Arctic or glacial conditions which preceded and followed them." ‡ We must not enter here upon the discussion of these so-called "mild and genial interglacial periods." We only remark that if such a submergence did take

* "Great Ice Age," p. 390. † *Ib.*, pp. 155, 157. ‡ *Ib.*, p. 158.

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place, it would certainly, so far as we can see, be accompanied by a great amelioration of the climate. It seems clear that the greater or less height of the land would tell powerfully on the climatal conditions by increasing or diminishing the extent of high land, and by shutting off, or more freely admitting, the ocean currents, which are the great distributors of warmth and equalisers of temperature. In short, there seems no reason to doubt that any submergence of the land is, *pro tanto*, in favour of a mild and equable climate.*

Now, we should naturally expect that the organic remains found in deposits laid down during these "long, mild, and genial" interglacial periods—especially if accompanied by physical changes favourable to the maintenance and diffusion of such mild conditions —would indicate more or less clearly the great change of temperature which had taken place, and would present a distinctly more southern *facies* than those which had been laid down under colder conditions. I need not remind my present audience of the close connection there is between temperature and species, and that this is especially the case with regard to the mollusca. Some species are so intolerant of cold that they barely touch the southern coast of Britain; and others are so averse to warmth that they scarcely reach our northern shores,—so nice is their dependence on conditions of temperature, and their restriction to certain climatal areas.† Shells have thus been taken to be most sensitive and accurate indicators of the prevailing temperature. In illustration of this, several geological writers have shown that some shell-beds on our eastern coast indicate colder conditions than those of the Clyde valley; and they account for this by saying that "the North Sea, cumbered with ice from Scandinavia as well as from Scotland itself, would in all probability have a lower temperature than the freer ocean"—though it was certainly far from being free of ice—"that washed the western sea-board." If "therefore it is not surprising that this difference of temperature should have taken effect and influenced the distribution of the fauna,"‡—much more,

* Those geologists, however, who most favour submergences (for they often suppose *several* of them) don't always observe this connection in their scheme of events; they frequently put the milder condition and the retreat of the ice *first*, and *then*, after a considerable interval it may be, the submergence.—"Great Ice Age," pp. 184, 329, 397, 410, 563.

† See, *e.g.*, Miller's "Sketch-Book of Popular Geology," pp. 329, 330.

‡ "Great Ice Age," p. 265, note.

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as it seems to us, should we expect this difference to appear in beds deposited during a long, mild interglacial period, when all the land of the country was lowered by 500 or 600 feet, and when a broad ocean sound filled the central valley.

What, then, is the nature of these shells found on this supposed sea-bottom near Airdrie, laid down at the very climax of such an interglacial period? Keeping by all we know—the *Tellina calcarea*—it is one of the most distinctively Arctic shells found anywhere in our glacial deposits, a shell marking extremely cold conditions, "not yet found living in the British seas, but abundant on the coasts of Greenland, boreal America, &c." (Miller), "living in the Arctic seas, not known as a living British shell" (A. Geikie). Is there really any value in shells as indicators of the prevailing temperature in any formation, if a "bed" of this *Tellina calcarea* is to be taken as marking a "mild interglacial period?" *

So long as anything like the present distribution of sea and land prevailed (and it is not contended that there was any material

* Dr. James Geikie alludes to this difficulty. He says, "I have spoken of these shell-beds [Chapelhall and others] as interglacial deposits, although their fossils indicate the pressure of a much colder sea than now flows round the British coast, simply because they are links in the chain of evidence which goes to show that the intense cold of the glacial epoch was interrupted by more or less prolonged intervals, during which milder conditions of climate prevailed." We confess ourselves unable to see how this Chapelhall bed, of strongly Arctic character, though deposited during a time of great submergence, can in any way serve to show the prevalence of "milder conditions of climate." Its evidence seems to be quite the other way. Dr. Geikie continues, "A very little consideration will suffice to convince us that, however cold the climate may then have been, Scotland could not by any possibility have presented such an intensely Arctic aspect as when the ice-sheet was at its thickest" ("Great Ice Age," p. 175). But was not this simply because there was less of it left to present any aspect at all? Judging from what is known of the habitats of this shell, the lands adjoining the seas in which it lived would be covered with ice and snow, and the seas themselves almost constantly laden with floating ice. And if this was the case in our country, even when it was submerged to a depth of between 500 and 600 feet, we fail to see the proof of an amelioration of climate.

[We trust our numerous references to Dr. Geikie's work will be excused, as it is the leading work on the subject. But fifteen years is a long time in Glacial geology (we mean in the study of it) and the numerous points of divergence that are now cropping up suggest whether it is not time for a *third* and *revised* edition?]

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difference in that respect during the Glacial epoch) there must always have been more or less of a warm ocean current from the S.W., reaching the shores of northern Europe in exchange for the cold current from the N.E., flowing southern along the shores of North America. This is in accordance with the great system of atmospheric and oceanic circulation, which again is a result of the greater heat of the tropics, and of the earth's rotation on its axis.*

It seems incredible, therefore, that there should be a submergence of the British Isles to the amount of between 500 and 600 feet—all the high grounds lowered and circumscribed to that extent, and the sea so much more freely intersecting the land—without a far greater amelioration of climate than is indicated by these Chapelhall shells. In other words, the nature of the organisms seem to be a further difficulty in the way of believing that this clay was actually deposited by the sea during a period of submergence. And these remarks, of course, apply to all so-called "high-level Arctic shell-beds." The higher the level, the greater the double improbability of their being (*a*) true "shell-beds," and (*b*) of Arctic species.†

* Nay, so similar in some respects to those now existing were the conditions during the Glacial epoch—the distribution of sea and land, the general configuration of the surface, and the prevailings winds and currents—that the areas of maximum precipitation seem to have been virtually the same as at present,—so that "the marks of ancient glaciers are most decided where the rainfall is now heaviest" (Jamieson, *Quar. Jour. Geol. Soc.*, 1874).

† Since this was read we have been reminded of the following passage in a paper by Sir William Thomson (Lord Kelvin) on "Geological Climate":—"A thousand feet of depression would submerge the continents of Europe, Asia, and America for thousands of miles from their present northern coast-lines; and would give, instead of the present land-locked and therefore ice-bound Arctic sea, an open iceless ocean, with only a number of small steep islands to obstruct the free interchange of water between the North Pole and temperate and tropical regions. . . . Now what must be the climate of a small island in an open iceless circumpolar sea? Temperate and quite free from frost except in hollows, we may, I think, safely answer" (*Transactions*, vol. v., part 2).

Of course, what his lordship here says of a depression of 1000 feet (which was taken simply by way of illustration) is true also in measure of a depression of 500 feet. Indeed, it is to be remembered that the principal change in the extent and contour of the land would be caused by the submergence of the *first 500* feet.—We have great pleasure in citing this passage as strongly corroborative of the argument just stated.

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(4) *Was the Submergence caused by Subsidence?*—These observations appear to hold good whatever theory we adopt as to the cause of the supposed submergence; and each theory as to that cause, we shall find, is attended with special difficulties of its own. Take the first and most obvious account of it, that there was an actual subsidence of the land, or depression of the earth's crust to this extent, in this and neighbouring parts of the northern hemisphere. This was the theory adopted by Sir Charles Lyell and all the earlier writers on the subject. Proceeding chiefly upon the changes of level that have been observed in Scandinavia (though there is no proof that these go beyond very narrow limits), Sir Charles supposed a gradual subsidence at the rate of about 2½ feet in a century, and that this might go on for nearly 100,000 years, till there was a submergence of over 2000 feet.* And, of course, this must have been followed by a re-emergence, in all probability equally gradual, and occupying a similarly long period of time. Passing over the improbability of such great oscillations of the earth's crust happening within comparatively recent times—while all through the Secondary formations and down to the later Tertiary deposits, the changes of level, as Sir Andrew Ramsay has shown, seem to have been comparatively insignificant†—passing also the improbability of such a great submergence (occupying this immense interval of time), leaving only such few and doubtful traces behind it; and merely noting that there is no proof of anything like such a submergence in other parts of the northern hemisphere,‡—let us take the much smaller submergence of between 500 and 600 feet, which is at present under our consideration. At the assumed rate of movement, a submergence of 550 feet would occupy 22,000 years, and the re-emergence an equal period, or 44,000 years in all—allowing the movement to have been constant and uninterrupted by any periods of repose. There seems to be ample time here—especially under the conditions supposed—for the accumulation and redistribution of considerable bodies of sediment, and, in short, for changes of no small extent in the aspect and physical geography of the country. Now, the theory is, that the re-elevation of the

* "Antiquity of Man," 3rd ed., chap. xiv.

† "Physical History of the Dee," *Quar. Jour. Geol. Soc.*, vol. xxxii.

‡ See paper already referred to, *Transactions*, vol. ix., part 1, p. 100.

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land was followed by a return of Arctic conditions, and a second period of glaciation. And it is to be noted that this second glaciation seems to have been very much a repetition or duplicate of the first. It is true that several authors speak of it as "milder," "less intense," "on a smaller scale," than the first; but when, according to their own showing, the Firth of Clyde again became so choked with ice that a wide-spreading sheet of it found its only available outlet across the midland valley to the German Ocean; when the Irish Sea was again filled from side to side with ice from the Southern Uplands, and the Cumberland and Irish mountains; when the ice from the N.W. Highlands again extended across the Minch, and over the northern part of the Island of Lewis; and when the British and Scandinavian ice once more coalesced in the German Ocean*—it seems a waste of words to say that this second glaciation was appreciably less than the first.

But if it be hard to account for a subsidence or depression of the earth's crust at that particular time, and equally hard to account for its subsequent re-elevation, it seems to add very much to the difficulty that, after these great changes, occupying several tens or scores of thousands of years, the land should be supposed so nearly to resume its former aspect; that the temperature and all the climatal conditions,—the configuration of the country, the height of the mountains, and the direction and inclination of the valleys,—everything should be so nearly the same over again as to produce that highly complex result, a second glaciation, in all respects so closely resembling the first.

It is this consideration which has led many eminent geologists, both in Europe and in America, to deny a second distinct period of glaciation altogether—believing rather in the oneness of the Glacial epoch, with, of course, considerable oscillations of the ice, than in two or more distinct periods of glaciation, distinct and yet so nearly alike.†

(5) *Was the Submergence caused by a Rise in the Sea-level?*—According to the other way of accounting for the submergence, "the sea may rise upon the land, without any movement of the land itself." As Mr. Adhémar and Dr. Croll pointed out, a great

* "Great Ice Age," pp. 159, 562, 564.

† Falsan, "La Périodé Glaciare," p. 211, &c. Wright, "Ice Age in North America," pp. 500-1.

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mass of ice in either hemisphere such as that which covered so many northern regions during the Glacial epoch would, of itself, by displacing to some extent the earth's centre of gravity, cause a rise of the sea in the hemisphere where the ice was in force. To what extent this would take place has been matter of considerable discussion and difference of opinion. But Dr. Croll's calculation was that the transference of the "ice-cap" (as it was then called) from the Antarctic to the Arctic regions might produce "a rise of the sea-level at the North Pole of 285 feet, and in the latitude of Edinburgh of 234 feet."* Dr. Croll thought there might be a considerable additional rise, resulting from the melted ice—assuming that the ice would melt on the one hemisphere more rapidly than it would form on the other—which seems to be doubtful, and may therefore be set aside. Here then, as Dr. Geikie remarks, we have "a *vera causa* of changes in the relative level of land and sea; and certainly it is remarkable that evidences of submergence should so often accompany marks of strong glaciation, as if the one were somehow dependent upon the other."† Let it be borne in mind, too, that this explains not only the submergence and its coincidence with the Glacial period, but what is equally important and equally difficult to explain on any other hypothesis, the re-emergence of the land when the ice-sheet diminished or passed away. So that it seems in all respects a more probable hypothesis than actual depressions and re-elevations of the earth's crust, happening, in some inexplicable way, at that particular time.

But if we adopt this as in all likelihood the cause of the submergence, then there must be some proportion between the cause and the effect. It is surely inconsistent to premise submergences of 1400 to 2000 feet, bringing in "actual subsidences of the land itself" to account for these, and leaving the more moderate ones to be accounted for by the ice-sheet alone.

Even as regards a submergence of between 500 and 600 feet in this country, it seems to be more than we are warranted in attributing to this cause. We have seen that Dr. Croll—who took larger data as to the mass of the ice than most physicists will allow—only estimated a rise of the sea from this cause, in the

* "Great Ice Age," p. 487.
† *Ib.*, p. 488.

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latitude of Edinburgh, at 234 feet. In North America, where an area of about 4,000,000 square miles was covered by ice (more than double the area so covered in Europe) with an average thickness, at its maximum, of a half or two-thirds of a mile—yet with this enormous mass of ice the American geologists compute that portions of the North Atlantic, and of the Arctic sea, would only be lifted "perhaps, on an average, two or three hundred feet higher than now."* And a most interesting point is that the traces of submergence increase to a certain point northwards, as might be expected if due to this cause. Thus, near Boston, and north-east to Cape Ann, the coast seems to have been submerged to a slight depth, probably not exceeding 10 to 25 feet. Proceeding towards the north and north-west, the elevation of the marine beds lying on the glacial drift increases to about 225 feet in Maine, about 520 feet in the St. Lawrence valley at Montreal, and 440 feet at a distance of 130 miles W.S.W. of Montreal; but eastward, along the St. Lawrence, it decreases to 375 feet opposite the Saguenay, and does not exceed 250 feet in the basin of the Bay of Chaleurs. Along the east main coast of Hudson Bay, and on Hudson Strait, and in the region S.W. from James Bay, the submergence indicated is about 300 feet. On the other side of the continent, in British Columbia and Queen Charlotte Islands, the evidence points to a submergence of only between 200 and 300 feet, which corresponds with the smaller mass of the ice in that direction.†

If these are the figures for the North American continent, with its enormous ice-sheets during the Glacial period; and if in Scandinavia, where there is evidence that the ice attained to at least double the dimensions which it had in this country, the greatest submergence appears to have been barely 600 feet—(and some geologists doubt if it was so much)—it is difficult to believe that in this country, with a far smaller and more limited ice-sheet, the submergence (if due to this cause) should be equal to, or even exceed, the maximum shown by these other countries. Let us try a little simple calculation on this point.

* Warren Upham; see "Ice Age in North America," p. 579. "Among American geologists the belief in a great submergence of the land in late glacial and post-glacial times is passing away" ("Great Ice Age," p. 480).

† "Ice Age in North America," pp. 580-1, &c.

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In America, as has been remarked, the phenomena are "writ large," they are presented with great clearness, and on an immense scale. Now, we find there that from latitude 40° to 51° N., or about 750 miles, the increase in submergence, or the rise in the sea level, seems to have been about 450 feet, or ·60 of a foot per mile ($7\frac{1}{5}$-inches).

Here, owing to our smaller area, our proximity to the sea, and the coalescing of ice-sheets from different quarters, the phenomena are perhaps less distinct and easily traceable.

But let us take two fixed points. Take England, south of the Thames and the Bristol Channel, to begin with. That district, according to Sir Charles Lyell, "seems to have remained land during the whole of the glacial period, at a time when the northern area was under water."* And Sir Andrew Ramsay concurs that there is no trace of glaciation—"no recognised boulder-beds in England anywhere in or south of the valley of the Thames."† Some geologists, however, more recently recognise a small submergence of that region—from 20 or 30 up to 50 to 60—at all events under 100 feet. If we say 100 feet in the latitude of the Thames valley, or $51\frac{1}{2}$° N., then our next fixed point will be on the coast of Norway, 65° N., where the submergence appears to have been about 600 feet. Assuming that there was a gradual uniform rise in the level of the sea from the south of England to the coast of Norway, which is the most probable hypothesis we can reason upon, and it is so far borne out by the facts of a similar kind in North America; we have here a rise of 500 feet in a distance of about 900 miles, which is equal to ·55 of a foot (or $6\frac{2}{3}$-inches) per mile. This is not far from the result we arrived at as regards America, a little less, as perhaps might be expected. Taking, then, our own country at this rate, 350 miles north of the Thames would give only $192\frac{1}{2}$ feet (or say 200) of a submergence; 400 miles, 220 feet, and even the extreme north of Scotland would only reach about 250 feet. Now this is very far short—much less than half—of what is required in the centre of Scotland for the supposed submergence under consideration. ‡

* "Antiquity of Man," 3rd ed., p. 275.

† "Physical Geology and Geography of Great Britain," 3rd ed., p. 239.

‡ It is sufficient for our purpose if these results, from a fair use of the known facts, are at all approximately correct.

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Thus, if we adopt the attraction of the ice as the probable cause of the submergence (or rise in the waters of the sea), we must reason from what we know, or can observe, of its effects in other parts of the world, and over the northern hemisphere generally; and all the facts we know regarding these seem quite opposed to a submergence of anything like 500 or 600 feet being possible in this country from this cause.

Tested by what is admitted regarding the "Second Glaciation."—We may note here, in passing, that the submergence which can be shown to have occurred during what is called the "second glaciation,"—which, from what has been admitted as to the extent of the ice and the effects it produced, must have been, as we have remarked, very much a repetition of the "first glaciation"—the submergence which occurred in the last cold period, and which, we may conclude, should be more clearly ascertainable than that which occurred in the first, seems to have been only about 100 or 125 feet.* This was the case, when the ice again attained such huge dimensions—when the whole country, except, perhaps, the highest peaks, lay buried under it, and great ice-sheets or systems of confluent glaciers extended all around it as before. Taking what is said of it by those who advocate it, it is hard to suggest any reason why the submergence which occurred during this so-called "second period of glaciation" should be only about one-fifth part of that which is claimed to have occurred during the first period, to which in all other respects it seems to have borne so striking a resemblance. I say it is hard to suggest any reason for this, if we proceed on the theory which we are arguing on at present, that the ice itself was the cause of the submergence.

Tested again by what is known of other Countries.—Referring again for a moment to other countries, we may note that, instead of the numerous oscillations and repeated submergences supposed by some geologists to have taken place in this country,† it seems there was in Norway just one partial submergence (which, as we have shown, there is every reason to believe, was greater than that

* Sir A. Geikie, "Text Book," p. 903. "Great Ice Age," pp. 254, 262.

† "How many submergences there were, we cannot at present, and perhaps never may be able to say."—*Op. cit.*, p. 188. We gather, however, that at least *three* or *four* distinct submergences are (or were) believed to be made out (pp. 184-5, &c.), which seems pretty well.

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which took place in this country); and that this was not followed by another glaciation, but by the retreat of the ice and the re-elevation of the land.*

To the same effect, Professor Wright states that the only changes of level connected with the Ice Age in North America of which there is satisfactory evidence are the following:—(1) A pre-glacial elevation of a few hundred feet; (2) a depression varying in different localities, but as a rule increasing northward, from 150 up to 520 feet—the greater number of instances observed being between 300 and 400 feet; (3) a re-elevation towards the close of the period, of the regions that were thus submerged. These, he says, "seem to be all the changes of level which are absolutely required to explain the facts in hand." †

Is it not worth considering whether (with a narrower limit certainly as regards the submergence, corresponding with the smaller scale of the other phenomena) these would not also explain all the facts in this country? We may reasonably assume that the phenomena of the Glacial epoch were exceedingly uniform all over the northern hemisphere; and any scheme of interpretation which holds good over the greater part of the area is *ipso facto* more probable than a scheme which is good for one locality only—for Lewis, or Wales, or the east of England, or the North of Scotland—and differs entirely from that proposed to account for the corresponding facts in other localities.

Recapitulation.—For all these reasons, which we leave to have such weight as may appear fairly to belong to them, we find it impossible to believe that this clay at Chapelhall is a true shell-bed marking a former level of the sea.

Passing over the preliminary objections that might be raised on account of the imperfection of the evidence on which it rests, and the little that is really known of it; and taking all we do know, we have touched upon these points:—

(1) Its local and limited character, and the absence of all traces of it in a number of other localities, not only in the neighbourhood, but on both sides of the central valley where these might be expected, and in other parts of the country generally.

* *Op. cit.*, p. 410.

† "Ice Age in North America," pp. 414-5.

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(2) The absence of marine organisms in the overlying Boulder-clay, which, if the sea had reached this limit, must have been largely formed of materials derived from the old sea-bed.

(3) If deposited during a period of great submergence and milder conditions, as had been alleged, it seems reasonable to expect, from all we know regarding the laws which regulate the distribution of the mollusca, that the marine organisms it contains would be of species indicating a more genial temperature than do those actually found at Chapelhall.

(4) If there was an actual depression and re-elevation of the land, occupying, according to all known data concerning such great crustal movements, scores of thousands of years, it seems highly improbable that the land should so nearly regain its former level just at the recurrence of another cold period, and so exactly resume its former condition, that an ice-sheet capable of depositing another great thickness of Boulder-clay composed of materials largely derived from the Western Highlands should again overspread the central valley of Scotland.

(5) If, on the other hand, the submergence was due to the mass and attraction of the ice itself, then we are met by the difficulties (*a*) that it is greatly in excess of the submergence traceable in other parts of the northern hemisphere, where the ice is known to have been in much greater force; (*b*) that the submergence traceable in these other parts seems not to have taken place at the same stage of the glacial epoch as this alleged great submergence in Scotland, *i.e.*, seems not to have been succeeded by a second glaciation; but to have taken place just prior to the final retreat of the ice and the "last elevation of the land;" and (*c*) that there is no degree of proportion discernible between this alleged submergence of 500 or 600 feet during the "first glaciation" and that which can be shown to have accompanied what is called the "second glaciation," which, however, from its extent and effects, seems to have been scarcely, if at all, inferior to the first.

Some of these reasons will doubtless appear more weighty than others; but taken altogether, we think they form tolerably strong ground against accepting this Chapelhall deposit as a true "shell-bed," and the submergence of "526 feet or more," which it has so frequently been taken to indicate, as proved.

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by the ice would be most likely to be deposited; and the conspicuous ridges of Boulder-clay all around, to which I have referred, corroborate this statement. It seems to be where the ice meets with some decided obstruction, that such things are most apt to be deposited by it—of which illustrations might be adduced from Caithness and elsewhere.* In short, this case at Chapelhall seems to present on a smaller scale what happened at Moel Tryfaen, and also on the Dublin and Wicklow hills, where such deposits of transported materials were left on prominent outstanding obstructions in the path of the ice.†

I need not pursue the subject further at present. The other "high-level shell-beds" in Scotland—those of Aberdeenshire and Nairnshire—I purpose considering on another occasion. Meantime, I am confirmed in the view I have taken of this subject, by finding that Sir Archibald Geikie, in the last edition of his "Text-Book," expresses himself with great caution and reserve regarding these "high-level shelly deposits." He says, "they are probably not conclusive proofs of submergence," for "they may have been picked up from the sea-floor by moving ice," as in the various instances to which we have already referred. He dismisses the shells at Moel Tryfaen as "probably not really in place;" and with regard to this instance at Chapelhall, he admits that "the layer containing them may have been transported by the ice-sheet,"—which is virtually giving up the case for submergence.‡

I venture to think that the more the matter is considered, and the difficulties against any other hypothesis fairly weighed, the more will this explanation commend itself to the minds of geologists. I accordingly submit that this instance of Chapelhall ought no longer to be cited as a proof of submergence.

* See Peach and Horne, *Proc. Roy. Phys. Soc. Edin.*, vol. vi.

† We may also notice in passing the colour of the clay—red, or, as Mr. Russell described it to Sir A. Geikie, "a fine reddish brick-clay." The clay proper to the Carboniferous rocks is, we need hardly say, of a much darker tint, "bluish-black, dull blue, or leaden." So that from this description, the shelly clay would certainly appear to be of an origin foreign to the district.

‡ *Op. cit.*, pp. 897-902, and "Scenery of Scotland," 2nd ed., p. 366.

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GLEN FRUIN—DISTANT VIEW OF MORAINE.

CARTER & PRATT, LEITH.

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No. XXVIII.—On a Glacial Mound in Glen Fruin, Dumbartonshire. By Dugald Bell, F.G.S. With Two Plates [Nos. XII. and XIII.]

[Read 28th May, 1891.]

Glen Fruin* is a quiet secluded glen, about 6 miles in length, extending in a north-westerly direction between Loch Lomond and the Gareloch, and opening off the neck of land which divides these lochs at between 200 and 300 feet above the sea. On the south-east it slopes towards Loch Lomond, of which the Fruin water is one of the principal affluents. On the west it is bounded by a range of hills 1000 to 1200 feet in height, which at the upper extremity, towards Garelochhead, subside into a col or pass of 600 or 700 feet. The upper part of the glen is composed of the mica and clay slates common to the Western Highlands. The lower part is formed of beds of the Calciferous Sandstone series, which have apparently been faulted down between the adjacent Old Red Sandstone and the older Silurian rocks.

The huge boulder of mica-schist, resting on the sandstone, at Callendoun, near the mouth of the glen, about 200 feet above the sea (and measuring 28 × 18 × 10 feet), was brought under the notice of the Boulder Committee of the Royal Society of Edinburgh by Mr. R. L. Jack, when engaged on the Geological Survey of the district, and was afterwards visited by the Convener of the Committee, the late Dr. Milne-Home, and figured and described by him in one of the Committee's annual Reports. By some mistake, as we formerly pointed out,† either Mr. Jack, or the Convener in copying his note, *reversed* the position of the boulder, stating that it lies "with sharp end to west and thick end to east"‡—the fact being that its sharp end is distinctly to E. (or S.E.), and its thick end to W. (or N.W.). Dr. Milne-Home considered it more particularly with reference to his favourite theory of floating ice or icebergs; his only doubt being whether it came down Loch Lomond and turned aside into Glen Fruin, or over from the west, from the neighbourhood of Loch Long and Loch Goil.§ He

* "Glen of Sorrow"—scene of a sanguinary conflict between the Colquhouns and Macgregors in 1603 (see Introduction to "Rob Roy.")

† *Transactions*, vol. viii., part 2, p. 256.

‡ "Second Boulder Report," p. 68.

§ "Second Boulder Report," p. 20.

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inclined to the latter conclusion, because this seemed to him to be the direction in which the "bergs" generally came—at least in the midland districts of Scotland—all difficulties being got over by supposing a sufficiently great submergence. It is to be noted that there are many other boulders in the neighbourhood, some of considerable size, up to heights of 500 or 600 and even 1000 feet.*

We need not here enlarge on the various objections to the iceberg hypothesis—as (1) the absence of any separate and distinct proof of such a submergence as the theory presupposes; (2) the difficulty of seeing where, in the event of such a submergence, the large icebergs required could be formed—besides the probability that there would then be, in this country, or in what was left of it, little or no ice at all; (3) by what possible main currents of the ocean (which alone could move them) these icebergs could be brought to many of the localities in which the boulders occur—land-locked bays and side-glens being necessarily quite out of their track; or (4) how they could pick up and carry forward specimens of the various kinds of rock submerged beneath them on their way, and lay down an accumulation of débris derived from far and near, but mainly from the immediate neighbourhood of where it is deposited.† For these reasons, and others that might be added, we reject the iceberg hypothesis, and conclude that such boulders owe their transport to a great sheet of *land-ice* which once filled the glen from side to side, proceeding from the Argyleshire mountains on the north-west, and overflowing the rock or col at the head of the glen, as also that at the head of the Gareloch, between it and Loch Long.‡

This view is strongly corroborated by the phenomenon which we have now to describe, viz., a remarkable mound or ridge of detritus extending for a considerable distance on the hillside to the east of the glen, in a direction transverse to the glen itself; and which, there can be little doubt, is a true terminal moraine left by the ice at this point during its retreat. We first observed it rather more than a year ago, when visiting the glen with a

* *Transactions*, vol. vii., part 1, p. 172, and vol. viii., part 2, p. 255.

† *Ib.*, vol. viii., p. 245, &c.

‡ As noticed many years ago by Mr. C. Maclaren, *Edin. New Phil. Jour.*, vol. xi.

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friend who wished to see the "big boulder" at Callendoun. Having satisfied our friend's curiosity in this respect, we proceeded about a mile farther by the road up the eastern side of the glen, and turned down the by-road towards Inverlaurin farm, in order to cross the Fruin by the bridge there, and so regain the Helensburgh road. In going down this by-way it struck us as being raised above the general level of the moor, and formed on the top of a stony or gravelly mound, which we thought was very unlikely to have been gathered for the sake of forming a farm road. It seemed more likely that a natural mound at this point had been taken advantage of for the purpose. This was immediately confirmed by the ridge or mound becoming too high and hummocky for the road, which then ran alongside of it, but still getting the benefit of the stony material. Having called the attention of our friend to what we had thus observed, we turned back a little way to ascertain if the line of mounds could be traced farther than the road by which we had come; and there certainly we did see it extending for some distance very distinctly up the hill on the opposite side. We had not time then to examine it more particularly; but a few weeks later we had an opportunity of following it more fully, and noting the particulars which it is the object of this paper to communicate.

Immediately to the north-east of the farm house of Inverlaurin, just behind the shepherd's cottage, the line of mounds is exceedingly well defined. From this point (about 300 feet above the sea) it extends in a north-east direction up to the public road (at 400 feet) where a schistose boulder of some size leans against it, as if specially to mark its position.* Across the road we see it rising very conspicuously in the same general direction, as a succession of green mounds on the hillside, as far as the boundary dike of the moor attached to the farm. Beyond this dike (450 feet) we follow it, still to the N.E., for more than a mile, to where the shoulder of the hill begins to curve round towards Glen Finlas. It continues wonderfully distinct all along its course—one part, to the north of the dike, rising from the moor almost as evenly as a railway embankment. Across the face of Shantron hill it "tails out" in a long upward curve, to about 700 feet, which may be distinguished from a considerable distance.

* Plate XIII., fig. 1.

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Of course it is not quite straight, but winds in and out, in a succession of little bays and promontories; nor is it quite level, but has higher and lower parts, showing in some places like a succession of little hills or hummocks. Its general direction, however, is, as we have stated, N.E. and S.W. The glen runs N.W. to S.E., so that the ridge is plainly transverse to the glen. Its height above the surface of the moor varies from a few feet to 10 or 12, and in some parts 20 to 25 feet; and its average breadth may be from 30 to 40 feet. The "burns" coursing down the hillside have cut into it, and even through it, in some places, clearly revealing its structure.* It is composed of stones, sand, and gravel promiscuously thrown together, with but faint traces here and there of anything like stratification. In short, it is typical moraine matter—as like as possible to the moraines we have seen near existing glaciers in Switzerland. The stones are chiefly mica and clay slates, with fragments of quartz and some felstones, and a considerable proportion of sandstones from the immediate neighbourhood—these last, as far as we observed, being more abundant near the middle of the glen. These stones are mostly angular or sub-angular, but a few are of a more rounded form. Scattered about at the base of the mound, and here and there on its sides and top, are larger boulders of various kinds, chiefly of the harder schists and quartzose conglomerates, which have been brought from a greater distance. We also found one or two well-rounded pieces of grey granite, with large crystals of felspar, similar to boulders found elsewhere on the west coast, on the shores of the Gareloch and Holy Loch, and on the opposite side of the Firth, near Gourock. The origin of those boulders was undoubtedly a tract of porphyritic granite extending around Meall Breac on the eastern side of the upper part of Glen Fyne. They occur in great numbers near St. Catherines on the same side of Loch Fyne.

On examining the stones imbedded in the mound, we find many of them distinctly striated, chiefly along the line of their longer axis. This is generally admitted to be a sure indication of glacial action. [Specimens shown.]

Altogether, there can be little doubt this is a "terminal moraine" of the great ice-sheet which once occupied the glen; and, we may

* Plate XIII., fig. 2.

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RIDGE OF MORAINE.

SECTION OF MORAINE.

CARTER & PRATT, LITH.

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add, it is one of the most notable and characteristic which we have seen in the West of Scotland.*

About half-a-mile farther down the glen, on the farm of Highfield, there are traces of lower and more gently sloping mounds, now under cultivation.

A number of detached mounds of considerable size occur at still lower levels, beyond the opening of the glen towards Loch Lomond. There are two near Banachra, one of them, the largest in the neighbourhood, called Dunfin (the hill of Fingal) rising about 100 feet above the surrounding ground, and bearing traces of a hill-fort on its summit. There is another farther down, near the farm of Nether Ross. These are, doubtless, relics of older moraines; and the locality, where the Loch Lomond and Glen Fruin ice must have met, seems a likely one for such accumulations.

Farther up the glen, about the middle and towards the head of it, though there are many boulders and hummocks of débris scattered about, we observed nothing like the distinct and continuous moraine which has been described. The upper part of the glen, we may note, is occupied by a long stretch of flat meadow land, which seems to be the bed of an ancient lake, "ponded back" no doubt by heaps of moraine matter, which the stream has long since cut through and washed away.

Returning to the farm house of Inverlaurin, the ground to the west of it slopes rapidly down to the channel of the Fruin, the waters of which have evidently from time to time swept a considerable breadth of the valley. On the other, or western side of the river, there are some well-marked ridges of sand and gravel extending across the moor in a direction south-west by south, which may very probably be a continuation of the same moraine.

Meantime this interesting relic of the "Ice Age" suggests some important considerations and inferences:—

1. We may take for granted, to begin with, that such a distinct and continuous line of mounds could only be formed by a sheet of land-ice.

* We learn that when the officers of the Survey were in the district they examined a gravel-pit which had been opened near Inverlaurin, and described it as "Earthy gravel, a few of the stones striated"; adding with a query ("?"), "moraine rubbish." They thus seem to have had a glimpse, at least, of the moraine; but, so far as we are aware, the long continuous line of it, which we have described, was not observed.

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2. It seems equally evident that there has been no submergence to this point *since* the mound was deposited. Its rough, undressed, unstratified condition—its very existence as a distinct mound—proves this. Had there been a submergence of as much as 500 feet since it was deposited, such a loose earthwork would soon have been demolished and effaced by the currents sweeping across this neck of land between Loch Lomond and the Clyde.

3. For the same reason we may conclude there could be no submergence to that extent *while* the mound was being deposited. Some geologists hold that the ice-sheet reached the sea as the land rose (assuming a submergence), and laid down heaps of detritus along the sea-margin. In that case such accumulations would undoubtedly have borne distinct marks of assortment and stratification, especially in localities where strong currents must have been in operation.

4. Further, in connection with such mounds, there is a striking absence of any proof of a "great submergence" *prior* to their formation. The advocates of such a submergence hold that there was a first or general glaciation, then a deep submergence, then a partial or local glaciation, by which all distinct traces of the submergence were removed. But a little reflection will show (*a*) that it is very improbable any subsequent local glaciation could remove all traces of the sea's presence at high levels, supposing it had been there;* and (*b*) even supposing such traces had been entirely removed by ice from every glen such as this, it seems reasonable to expect that they should at least be discoverable, more or less, in the heaps of débris which the ice has so frequently left near the mouths of these glens. All over the country there are innumerable glacial mounds and heaps—the "sweepings" of glens which, in the case of the alleged submergence, must have been sheltered inlets of the sea, favourable to a great variety of forms of marine life. Can any good reason be assigned why these heaps, as well as the Boulder-clay of the country generally, should not abound in fragments of marine fossils, if there had been such a submergence, instead of being, as they are on the whole, quite destitute of organic remains?

This argument is not founded on a supposition, but on a fact. Wherever the ice can be shown (by the striæ on the rocks, the

* *Transactions*, vol. ix., part 1, p. 109.

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stones in the "drift," &c.) to have passed over what is still a sea-bed, or must have been so during a very moderate submergence, there also numerous fragments of sea-shells are found in the drift or Boulder-clay; as in the instances of Caithness, Arran, Drymen, South Ayrshire, Holderness, Cromer, Lancashire, &c.

The argument is strengthened also by a consideration of the long periods of time which, it has been estimated, the gradual subsidence of the land to the extent or degree supposed, and its equally gradual re-emergence, must have occupied.* All traces of such a prolonged occupation by the sea would not be easily removed or obliterated.

The advocates of a "great submergence" have, therefore, these two facts to account for—(1) the absence of all clear proofs of such submergence *in situ* at the high levels to which it is supposed the sea attained; and (2) the absence of all evidence of it in the débris *derived from* these high levels.

5. The prominence and continuity of this line of moraine shows that the ice must have remained at or near this point for a considerable time—this must have been, for a long period, the average limit of the lower edge of the ice-sheet. It must evidently have taken a long time to accumulate such heaps of débris from the waste of the surrounding hills. The ice had doubtless many oscillations —periods of retreat to some extent, during which some inner or upper lines of moraine were formed; succeeded by a fresh advance when these were again borne forward and incorporated with an older and lower line. But this line, which remains so wonderfully distinct, may be taken as representing its average limit during a long period, and as, therefore, indicating a prolonged continuance of tolerably uniform climatic conditions. The question arises, can we trace similar well-marked lines of moraine at about the same level in other glens? If so, they may furnish additional proofs of a long interval of approximate uniformity in the climate. They may also confirm, in some measure, our observations regarding the alleged submergence.

Now, we have been struck by the fact that, in other parts of the country where similar terminal moraines have been found, they seem frequently to appear in a distinct and noticeable form about this same level of from 300 to 400 feet. Thus Mr. Jamieson

* "Antiquity of Man," p. 485.

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of Ellon, who has contributed so many valuable observations on Glacial geology, states that he observed "a remarkably fine series of moraines in the valley of the Feugh, which is a tributary of the Dee. These moraines occur at levels of 300 and 400 feet." He adds, "they appear to be perfectly undisturbed, and, so far as I can judge, have never been touched by the sea since they were formed."—Another moraine farther up the valley "comes down below the level of 300 feet."—Two miles farther up, there is another "fine moraine at a level of about 300 feet." Its great size "marks a very long pause of the glacier here."—And still farther up there is "a fine little moraine at an altitude of about 440 feet, forming a characteristic crescent-shaped ridge," evidently "just as the glacier left it."—On the south side of the Grampians also, Mr. Jamieson states, he found similar terminal moraines at levels implying similar glacial conditions. "In Kincardineshire," he says, "I observed one at Drumlithie, near the railway station there, at an altitude of 280 or 300 feet above the sea, formed apparently by the glacier of the Bervie, a small stream which takes its rise among hills of from 1500 to 1700 feet in height. When this moraine was formed the glacier was seven or eight miles long." Mr. Jamieson continues, it "appears to me to be a terminal moraine. It consists of a long narrow mound, or series of mounds, from 20 to 30 feet high, with sides sloping at angles of 20° to 30°, curving in a crescent or horse-shoe form, with the convexity seawards. So far as I could make out, it is composed of coarse gravelly débris, irregularly piled together. . . The action of the sea would rather level such a mound than make it."*

This is exactly similar to the moraine we have been describing; and the Bervie glacier seems to have been almost a duplicate of that in Glen Fruin.†

Now, in all these cases, as Mr. Jamieson has pointed out, "the glacier, and not the sea, was the last occupant of the surface."

* "On the Last Stages of the Glacial Period in North Britain," *Quar. Jour. Geol. Soc.*, 1874, pp. 325, 326.

† We do not mean to represent that about 300 feet is the lowest point at which such moraines appear in a distinct and undisturbed form. On the contrary, they come much nearer the existing sea-level in many localities where the mountains approach the coast. But many of the average-sized glaciers would certainly stop at some distance from the sea; and, as shown, many of them seem to have halted long about the present 300 feet line.

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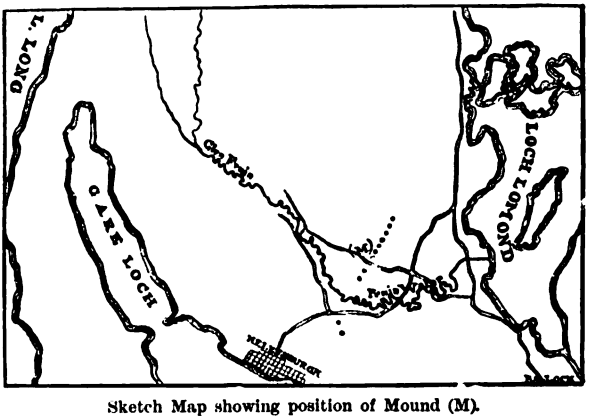
The only point on which we differ from this esteemed observer is that he favours a previous "great submergence," of which, as we have said, we think the proofs are lacking.

6. Another point of some interest is the comparative absence of any such lines of moraine in the upper parts of the glen—as if the ice-sheet, which had remained long about this level, when it did begin to give way had not made a similar lengthened pause at any subsequent stage. From the comparative absence of such well-marked terminal moraines in the middle portion of many glens and valleys, it has been inferred that the ice must have given way with considerable rapidity at last, not remaining long enough at any given point to form any very distinct accumulation of débris. Thus, Mr. Jamieson has observed, there are long intervals between such moraines in the valley of the Dee, as if the ice there had retreated by large stages. "Ten miles up the valley we find indications of a halt" at the Loch of Drum. "At Aboyne (20 miles farther up) there are indications of another halt." But "the longest and most decided pause" has been near Ballater, about 40 miles from Aberdeen. Other moraines of later origin are to be found in the upper branches of the Dee, at from 1600 to 2000 feet. These facts lead to the conclusion that at times "the ice seems to have receded rapidly over a wide area without leaving any marginal deposits." This corresponds also with what may be observed in Glen Fruin, and doubtless indicates the decided climatic changes which ushered in the close of the Glacial epoch.



Sketch Map showing position of Mound (M).

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SUPPLEMENTARY NOTE.

A note may be added on a suggestion which has been made by one or two members of the Society who have visited the moraine, viz., that it may possibly be the *lateral* moraine of a "branch" of the Loch Lomond glacier which here extended across the neck of land between Loch Lomond and the Clyde. To this there seem several formidable objections:—

1. Glaciers do not turn aside, or send out "branches," unless some obstruction compels them. Their tendency and practice is to move straight on, disregarding "openings" that do not lie in their direct path. They are unlike rivers in this respect, which spread out and turn aside on every opportunity. Hence glaciers often pass straight across lateral valleys, blocking them up, and forming lakes in them.

Now, what could make the Loch Lomond glacier turn aside, or send out a "branch" in this direction?—just where the loch opens out to its widest, and with the Vale of Leven on the one hand, and Strathendrick and Strathblane on the other opening out before it.

2. If its way in that direction was open, it is equally certain that its way in this direction was barred. There was "no thoroughfare" for it this way. There is every indication that the Firth of Clyde at this part was completely blocked by ice proceeding from the mountainous region around Loch Goil and Loch Long, which was in such mass that it passed straight across what is now the opening of the Firth, and over the hills behind Port-Glasgow and Kilmalcolm. It also pressed easterly into the Gareloch, into Glen Fruin, and along the hills near Helensburgh. It seems quite clear that the ice which came down Glen Fruin, instead of turning westward towards Helensburgh, moved still eastward towards Loch Lomond, and at its maximum coalesced with the ice there.

3. This is confirmed by the striations which were visible some years ago on a sandstone quarry near Crosskeys, to which I have formerly referred. ("Among the Rocks round Glasgow," p. 162.)

4. The conclusion that this is a terminal moraine of the Glen Fruin glacier seems to accord better with all the features of the moraine itself—its general form and direction, its greater prominence near the centre of the glen, and the materials of which it is composed.

Looking at all the features of the place, it seems quite probable that the lower part of Loch-lomond might be almost, or entirely, free of ice long before the Fruin glacier disappeared from the glen.

A few other localities in the West of Scotland, where well-marked moraines may be seen are—near Balmaha, Ardlui (head of Lochlomond), Glenfalloch, Balquhidder, Glen Dochart, Aberfoyle, Lochgoil near Carrick Castle, Glen Messan, and Bridge of Weir. D. B.

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No. XXIX.—The Ardrossan Shell-mound, with an Account of its Excavation. By John Smith. With a Plate [No. XI.]

[Read 9th March, 1891.]

In various parts of the world, notably along the Baltic coasts of the Danish islands, the eastern coasts of America, and near the shores of many of the Western Islands of Scotland, are found mounds of varied size composed for the most part of shells of the edible species of molluscs, such as limpets, periwinkles, cockles, and oysters. Interspersed with these are found the bones of many mammals and birds; also weapons and tools of flint, dolerite, horn, bone, and wood, including celts, scrapers, chisels, arrow-heads, sling-stones, anchor stones, and other articles which had been made and used by a prehistoric race of men.

In Denmark these mounds, which are called kjökken mödding, reach the dimensions of from 100 to 1000 feet in length and from 3 to 10 feet high. They have yielded many implements made of similar materials to those above mentioned; but no articles manufactured from any kind of *metal* have ever been found in them. From this circumstance these shell-mounds have been referred by archæologists to the neolithic division of the Stone age. The shell-mounds of the American coasts have a great resemblance to the Danish ones, also containing implements, bones, &c., and are supposed to have been formed by the aboriginal inhabitants previous to the occupation of America by the "white man."

The Scottish shell-mounds are, generally speaking, smaller than any of the others, but, like them, contain the bones of animals, and stone, horn and bone weapons and implements. In the Western Islands of Scotland the shell-mounds often contain a kind of stone implement still used by the islanders, and called "Orst Barnach," or limpet-hammer. In some mounds on the Island of Oronsay, which I examined in company with Mr. Galloway, these limpet-hammers were rather common. They were simply, in this case, selected pieces of clay-slate suitable for holding in the hand, which by constant use in shoving the limpets from the rocks, had assumed, at the ends, somewhat the appearance of a blunted "jumper." Amongst the implements there was another type, which puzzled us to understand what it had been used for. Only about the size of a finger (some examples not half so big) it was

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sharpened in the manner of a polished celt, although the body of the implement had not been worked or polished but had simply been selected for its natural shape. The great peculiarity about these Oronsay shell-mounds is the distance they are from the present shore-line, which strongly suggests the idea that there has been a considerable rise of the land since their formation. As will be seen further on, the evidence furnished by the Ardrossan shell-mound is in the same direction, almost demonstrating, in fact, that there has been a rise of a good many feet since the first occupation of this part of the Ayrshire coast by the shell-mound builders. It is this part of the subject which gives the mound its peculiar geological interest.

The Ardrossan shell-mound is situated on the south-west side of the Cannon Hill, close to the Ardrossan station of the Glasgow and South-Western Railway, the whole length of its north-east side lying against and under the rocky side of the hill. It measures 102 feet in length, with an average breadth of about 16 feet, but it has been much broader before the station was formed, a considerable portion having been removed, and a complete longitudinal section exposed, by the railway works. Its length, which appears to have been at one time somewhat greater, is mostly overhung a few feet by the rock-face; and facing the south-west, as it does, the place must have formed a snug shelter for its human occupants. Its formation appears to have been a slow process, and, as will be presently seen, it has been deserted at intervals for considerable periods of time. By their practice of always throwing the castaway shells and bones on the floor, the inhabitants seem to have gradually shut themselves out of the best part of the shelter, which had become more or less filled by the débris of their repasts and feasts. For its whole length the mound rests on a surface sloping upwards, as will be seen from the longitudinal section given in Plate XI. Having had the contents turned bodily over, with the exception of a few feet at the upper end where it would have been risky to do so, I found that underneath the whole of it, and resting on the rock, there was a bed of Raised-beach sand and gravel, about a foot in thickness, and containing rolled shells.

That this place had been occupied by man shortly after the waves left it was clearly evident, as there had only been time

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sufficient for a layer of earth little more than *half-an-inch* in thickness to form on the top of the gravel, nor had there been time for any talus of fragments from the rock-face to gather upon the gravel before the inhabitants began to throw down the shells and other debris upon it. In fact the talus of rock-splinters was formed *on the top of the mound*, as will be seen from the cross-sections (Plate XI., figs. 1 to 5), demonstrating at once its antiquity, and affording some guidance to the time of its commencement. Another point in favour of its antiquity is the fact that many specimens of a spiral mollusc, *Trochus lineatus*, were got in the mound, and must have been common on the then-existing shore. This mollusc is now extinct in the Clyde, and in the West of Scotland, and has only been found in the Clyde district once before as a *fossil*, Mr. David Robertson having got it in the Raised-beach strata of Millport, near the College.

Cockles appear to have been very rare in the sands of the neighbourhood, as only two valves were obtained from the mound, and of spout-fish only one small valve, while the "hugger-fish," *Tapes decussatus*, the "horse mussel," *Mytilus modiolus*, and the "clabbydoo," *Mya* of various species, were totally unrepresented. The horse mussel is rare as a fossil, and diminutive in size in the Raised-beach beds of Ayrshire, as is also the hugger-fish, and the clabbydoo is apparently absent from them. The species of the latter shell-fish most frequent in this district at the present day is *Mya arenaria*. In the lower estuary of the Garnock it was very abundant, in muddy and gravelly sand, twenty years ago. To discover their whereabouts one had nothing to do when the tide was out but to stamp on the wet sand, when numbers of small squirts of water would rise, at once revealing the exact position of their holes. But this species has been almost exterminated in this locality by the people carrying them off for food. A boy whom I met with a cargo one day spoke highly in their praise, declaring that they were "better than beef." The other species, *Mya truncata*, which was abundant during the Glacial period, is not found in the Raised-beaches of this locality, but appears at the present time, though very rarely, in this district of the Clyde.

The two principal shell-fish which had been used for food by the shell-mound builders were the periwinkle and the limpet, occasional

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specimens, especially of the latter, being large and ponderous. A few specimens of the small shore variety of the whelk, which is still common under stones on the north Ardrossan shore, were got in the mound; but of the larger variety, which lives on a sandy bottom and is frequently thrown ashore during storms, not a single specimen was obtained; mussels were not very common, and oysters were scarce. The edible crab was represented by a single claw, and the lobster was totally absent. Of fish remains only a few bones of the cod and conger eel were obtained, so that these ancient people evidently did not belong to an eminently ichthyophagous tribe. On the contrary, they had been great flesh-eaters, as is evidenced by the remains of the land animals upon which they fed. Although, like their contemporaries in the Western Islands, they lived largely on limpets, not a single "Orst Barnach" was found in the Ardrossan mound. There is evidence that they ventured out to sea, probably in small canoes, for a stone anchor with a groove cut round it, for the purpose of fastening it with some kind of rope, was got.

I commenced the exploration of the mound at the lower and wider end, and worked up hill, keeping, as far as possible, the full breadth and depth of the face before me, and testing the depth and quality of the underlying Raised-beach gravel now and then. Amongst the first articles turned up were a few fragments of very rude hand-made pottery of exceedingly coarse quality and badly burned. This kind of pottery is very rare on the Ayrshire sands, the reason evidently being that such imperfectly put-together material could not withstand the disintegrating influences of the weather for any length of time. The pieces got in the mound probably owe their preservation to their having been well covered up from exposure.

Having got a proper working face formed, I measured the first section as follows, in descending order:—

1.	Talus, on top of mound and lying against rock face.	
2.	Shell bed, - - - - - - -	6 to 18 inches.
3.	Reddish soil, - - - - - -	½ ,,
4.	Raised-beach bed, - - - - - -	4 to 12 ,,

No. 2 bed was for the greater part composed of *Littorina littorea* and *Patella vulgata*, with a few *Buccinum undatum* (small variety), *Ostrea edulis*, *Mytilus edulis*, *Littorina obtusata*, and *Nassa reticulata*. The last two are not now considered edible

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species, and possibly may have been carried up by the children to play with, or perhaps gathered with the others and thrown out.

A great many jaws with teeth, and bones were obtained, all the latter which had contained marrow having been split open. Under the ledge of rock at point *a* [see Plate XI., section 1], and imbedded in the mass of shells, was a human upper jaw without teeth, which had evidently been knocked out with a stone, splinters of the jaw having been broken off in the process. On finding this grim relic my first impression was that the people who lived here had been cannibals, the jaw having evidently been thrown in the most matter-of-fact way on the general shell-heap, while probably the teeth had been kept to make a necklace or other ornament. Further evidence, however, obtained during the exploration showed that, although the mound-men had feasted, probably during "hard times," on their own species, they were not habitual cannibals, for the whole human remains obtained seemed to show that not more than two human beings had been devoured.

My next cut was up to a boss of rock 10 feet long by 5 feet wide, which I have named the *Cannibal's Seat*. Working in between this boss and the overhanging rock-face the section was found to be as follows:—

	Feet.	Inches.
1. Talus of rock débris.		
2. Rock débris, mixed mostly with periwinkles,	1	6
3. Black layer, - - - - - - - -	0	1
4. Shell and bone bed (with a bone implement),	1	6
5. Earth, - - - - - - - - -	0	0½
6. Raised-beach gravel, with rolled shells, - -	1	3

Besides the shells already mentioned a valve of *Mactra subtruncata* was got in this cut. In the bottom layer of shells, but not touching the Raised-beach bed, occurred a well-rounded boulder about 2 cwts. in weight, having probably been used as a seat. The black layer (3) had evidently resulted from this narrow pass between the boss and the ledge having been used by the occupants as a pathway to the higher reaches of the mound. Next the boss in this bed the shells were mostly periwinkles, whilst under the ledge they were principally limpets. Had the limpets been thrown under the ledge to keep their sharp cutting edges away from the bare feet of the occupants? Under the ledge of rock, both above and below this spot, the shells and bones were cemented

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together into a solid mass by stalagmite, the lime having been derived partly from the overhanging rock and partly from the decomposition of the shells by rain-water. Part of a human lower jaw was got in the mass of shells (at *b*, Plate XI., section 2), and about a foot above the Raised-beach bed; it had three well-preserved teeth. Near the top of the same bed a well-made diamond-pointed bone chisel, a rude implement made of a human bone, and several human vertebræ, were obtained. Having worked up round the "Cannibal's Seat" an open face was again made, and here (at *c*, Plate XI., plan), the remains of a fire were come across. It had been kindled on the Raised-beach some 30 feet above present tide-mark, and showed that from the first occupation these people had been acquainted with the use of fire. Evidently, however, they had not roasted any of their meat, as none of the bones showed the touch of fire. In this cut the sandstone anchor already referred to was got. It measured 7 inches in length by 6½ inches at one end and 8 at the other; the groove round it having apparently been chiselled out with a stone. The first valve of the edible cockle, *Cardium edule*, was obtained here, as also three specimens of the dog winkle, *Purpura lapilis*.

The section (Plate XI., no. 3), at this part of the mound measured—

	Feet.	Inches.
1. Talus.		
2. Shell and bone layer,	1	8
3. Shell-meal,	0	2
4. Shell and bone layer,	1	8
5. Earth,	0	0½
6. Raised-beach bed,	1	0

The layer in this section of what I have called shell-meal (3) was composed of thoroughly decomposed shells and bones, and showed that the mound, or at least this part of it, had been deserted for a period long enough to allow the exposed organisms to become completely rotted away; but to this point I shall refer more fully again. In this cut was got a fragment of one of those curious perforated stones which Mr. James Bennie found in the bed of the Clyde at Glasgow, see *Transactions* (vol. ii., p. 114), and which he supposed to have been used as "sinkers" for the fishing-lines or nets of the old Clyde canoe-men.

From the Ayrshire sands I have gathered several of these

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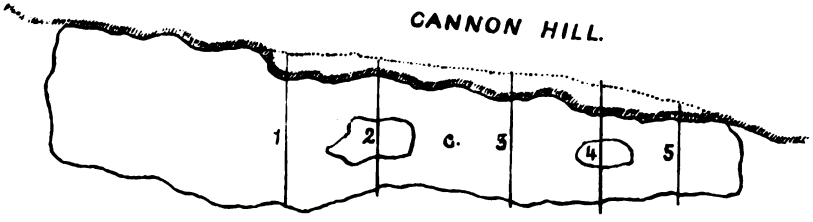
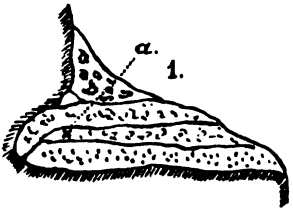
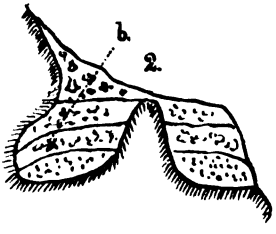


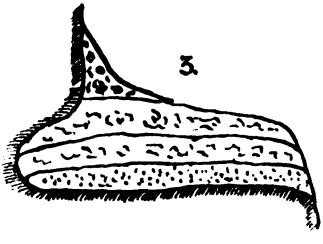
PLAN.

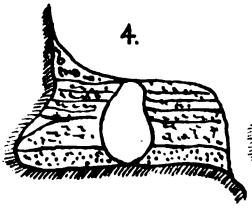
LONGITUDINAL SECTION.

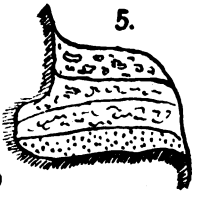
Level of Railway.











CROSS SECTIONS.

ARDROSSAN SHELL MOUND.

J. SMITH, DELIN. CARTER & PRATT, LITH.

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perforated stones, and, like this one, the holes have always been made from both sides, meeting in the centre. They are of two kinds, those made of stone, which appear to have been real sinkers, and those made of gas-coal, which are of the rudest description of workmanship, and the use of which is not so evident. My idea of these latter is that they were kept as charms, or perhaps reverenced and regarded as a sort of sleeping *fire-god* or *sun-god*, seeing that they were composed of a substance that would burn and flame. Of course, any beach pebble would have been more effectual as a sinker than one of these light pieces of gas-coal.

At the top of this section was got a piece of wheel-turned, glazed pottery. This was the first indication of a substantial advance in the arts, but, as we shall see further on, it belonged to a period posterior to that of the shell-mound. In the lower part of this cut were several fragments of a human skull; it had not parted by the sutures, but had evidently been smashed up to get at the savoury intellectual morsel within. One single valve of *Cardium edule* turned up here.

The next cut gave the following section:—

	Feet.	Inches.
1. Talus.		
2. Shell and bone layer	2	0
3. Reddish soil,	0	6
4. Shell and bone layer,	1	0
5. Earth,	0	0½
6. Raised-beach gravel, with large rolled stones,	1	0

After working round between a mass of fallen rock and the rock face, the next section was as follows:—

	Feet.	Inches.
1. Talus.		
2. Sandy soil, with pottery and slag,	0	6
3. Shell and bone layer,	1	0
4. Shell-meal,	0	2
5. Shell and bone layer,	1	0
6. Earth,	0	0½
7. Raised-beach gravel, with large rolled stones,	1	0

This last section gave us a new deposit—the sandy soil (2) with pottery and slag—which threw much-needed light on the relationship between the pottery and the slag, and showed very distinctly that their period was posterior to that of the shell-mound. All the pottery was of the wheel-turned description, and glazed; the slag was very dark in colour, and heavy. Both the

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slag and the pottery were of the same description as those I have often found on the Ayrshire sands, and introduced us to a period when man was acquainted with metal and the use of the potter's wheel. The "bill of fare," as indicated by this bed, was not so rich and rare as it had been during the shell-mound period; with the pottery and slag were only got a few periwinkles and the bones of rabbits and hares.

It is interesting thus to be able to compare this later period with the shell-mound period; this never before could be done with data supplied by the shifting Ayrshire sands, which mix all the remains of the various ancient periods together. But I am inclined to think that there is still another period, if not two, awanting, viz., the flint period and the bronze period, and the time they occupied may be represented better by the next section, where 9 inches of *earth* come in between the pottery and slag-bed and the top of the shell-mound. Not a trace of flint was found in the shell-mound, nor in the pottery and slag deposit. The flint and bronze periods are well represented in Ayrshire, and it appears to me that these ancient periods should read thus—

1. Slag and wheel-turned pottery period (the most recent).
2. Bronze period.
3. Flint period, with arrow-heads, scrapers, &c.
4. Shell-mound period, with hand-made pottery.
5. Period of the 20 to 40 feet Raised-beaches.

The old hand-made urns, with burnt bones, flints, polished celts, and hammers, should probably be correlated with the flint period.

The last section (Plate XI., no. 5), at 12 feet from the upper end of the mound, was as follows:—

	Feet.	Inches.
1. Talus, earth and large pieces of sandstone.		
2. Decomposed shells, bones, and earth, with wheel-turned pottery, and slag, - - -	1	2
3. Earth and bones, - - - - - -	0	9
4. Decomposed shells, - - - - - -	0	3
5. Shell-meal, - - - - - - - -	0	3
6. Earth, - - - - - - - - -	0	0½
7. Raised-beach of sand and gravel, - - -	1	0

This section was near the upper end of the mound, and the shells and bones were all in a decomposed state.

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The last bit of the mound to be excavated was the part outside of the fallen rock (Plate XI., section 4), as follows:—

		Feet.	Inches.
1.	Earth and shells,	0	4
2.	Shell-meal,	0	4
3.	Shell and bone layer,	0	2
4.	Shell-meal,	0	4
5.	Earth and shell layer,	0	6
6.	Shell-meal,	0	2
7.	Dark band,	0	0½
8.	Earth and shell layer,	0	6
9.	Shell and bone layer,	0	5
10.	Earth,	0	1
11.	Raised-beach bed, of sand and gravel,	1	0

This was by far the most interesting section of the whole, and afforded evidence that the mound had been deserted, for considerable periods, at least three times during its accumulation.

Throughout the extent of the mound were found a number of hammer-stones, a few very much worn, but the bulk of them had been little used.

All through the mound were found limpets having a hole perforated in the apex. Some were so much decayed that it was impossible to say whether these holes had been made artificially or by decay. Many had undoubtedly been made artificially, and it is most likely that they were strung like beads, possibly on to a strip of hide, and used as ornamental shell-belts, or *wampum*, after the manner of the Red Indians, for savage tribes, as well as more civilized ones, like to be "braw."

To Mr. E. T. Newton, palæontologist to the Geological Survey of England and Wales, I am indebted for the following list of animals, the bones of which were identified by him from a selection of 261, which I made from the whole mass of those found in the shell-mound, and which I sent up for his inspection:—

1. Man, *Homo sapiens.*

First rib, one.	Fragments of skull, four.
Second left rib, one.	Right radius, one.
Cervical vertebræ, six.	Left ramus with 4 teeth, fragments of one.
Dorsal ,, two.	Upper maxillaries, toothless.
Lumbar ,, one.	Teeth, a few loose.
Right mastoid, one.	

2. Long-faced ox, *Bos taurus*, var. *longifrons.* Mr. Newton thinks that the ox bones probably all belong to this species. Abundant.*

* From No. 2 onwards the species are given in the order of their abundance.

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3.	Goat, *Caper hircus.*	Common.
4.	Dog or Wolf, *Canis lupus* (?)	,,
5.	Sheep, slender legged.	,,
6.	Red Deer, *Cervus elephas.*	,,
7.	Pig, *Sus scrofa.*	,,
8.	Badger, *Meles taxus.*	Frequent.
9.	Rabbit, *Lepus cuniculus.*	,,
10.	Roebuck, *Capreolus caprea.*	Scarce.
11.	Hare, *Lepus timidus.*	,,
12.	Fox, *Canis vulpes.*	,,
13.	Horse, *Equus, sp.?*	,,
14.	Otter, *Lutra vulgaris.*	,,
15.	Cat, *Felis catus.*	,,
16.	Beaver, *Castor fiber.*	Rare.
17.	Weasel, *Mustela vulgaris.*	,,
18.	Seal, *Phoca, sp.?*	,,
19.	Grey Goose, *Anser cinereus.*	
20.	Pheasant, *Phasianus* (?)	One doubtful bone.
21.	Oyster Catcher, *Hæmatopus ostralegus.*	
22.	Red Grouse, *Lagopus Scoticus.*	
23.	Herring Gull, *Larus argentatus.*	
24.	Razorbill, *Alca torda.*	
25.	Puffin, *Fratercula arctica.*	
26.	Guillemot, *Uria troile.*	
27.	Conger Eel, *Conger vulgaris.*	
28.	Cod, *Gadus morrhua.*	
29.	Edible Crab, *Cancer pagurus.*	

From the above list it will be seen that the Ardrossan shell-mound builders were no ordinary mortals, but a race of noble savages, monarchs of all they surveyed, hunters of the mountain bull, the stag, and wild boar, clothed during the winter months with the skins of some of the larger animals, and probably having their own tattooed. But they certainly were not the poor painted savages, grubbing up and feeding on roots and herbs, that certain authors, evolving "unwritten history" from their imaginations only, love to depict the ancient Briton. Their occasional diet of shell-fish may have been partly from necessity, partly to give a relish to their more substantial food, which, by all the evidence we can gather from the mound, must have been eaten raw; although we have seen that they were certainly acquainted with the use of fire.

On showing the list to a friend, he remarked that probably no "mixen" of the present day in the United Kingdom could show the evidence of a greater variety of food.

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The only extinct Scottish animal, the remains of which were found in the mound, is the beaver. The two species of deer—the red deer, and the roebuck—would also probably have been extinct by this time had they not been protected. A number of the bones of the dog (or wolf, for anatomically it is impossible to draw a distinction between these animals) indicated individuals of large size. If they are bones of the wolf, of course this is another extinct animal. But if of the dog, it shows that these people had a powerful race of dogs, as well as horses (which, like the Tartars, they seem to have eaten, probably when they were done with them), with which to hunt their larger game.

It is astonishing to see the dog (or wolf) named amongst the more common species. Can the shell-mound men have eaten these animals? It is well known that some savage tribes at the present day feed their dogs on vegetable substances, so that during times of scarcity they may be used for food, their flesh by such feeding becoming palatable and wholesome, although when dieted on flesh it is rank and nauseous. In the present instance it is not within our knowledge what kind of vegetable matter they could have fed their dogs upon, there being no evidence in the mound that they were acquainted with any of the cultivated cereals.

The following is a list of the shell-fish found in the mound:—

Limpet, *Patella vulgata.* Abundant.
Periwinkle, *Littorina littorea.* ,,
,, ,, *obtusata.* Frequent.
,, ,, *rudis.* Rare.
Trochus lineatus, now extinct in Clyde. Frequent.
Silver Buckie, *Trochus umbilicatus.* Frequent.
The Groat, *Cypræa Europeæ.* One specimen.
Dog Whelk, *Nassa reticulata.* Frequent.
Roaring Buckie, *Buccinum undatum*, small shore variety. Frequent.
Dog Winkle, *Purpura lapilis.* Frequent.
Spindle Shell, *Fusus*, sp.? A fragment.
Edible Mussel, *Mytilus edulis.* Scarce.
Spout-fish, *Solen siliqua*, of small size. A fragment.
Aitken, *Mactra subtruncata.* A few valves.
Oyster, *Ostrea edulis.* Scarce.
Edible Cockle, *Cardium edule.* Two valves.

From the above list it will be seen that in the matter of shell-fish the *piece de resistance* was certainly furnished by the two species, the limpet and the periwinkle; the former, generally speaking, prevailing in the bottom part of the mound, and the latter in the

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upper. The other edible species are conspicuous by their scarcity, and two good edible ones, the "hugger-fish" and the "clabbydoo," are not represented. It will be observed that the rare or absent species are such as live in holes or under sand. Was the ancient Briton not acquainted with this fact, or were these molluscs scarce or absent from the district? From what has been already said I am inclined to hold the latter view. Two land shells were also obtained, *Helix nemoralis* and *H. nemoralis*, var. *hortensis*.

After the mound had been turned over, and the rain had washed the surface of the debris, I obtained a pair of bone needles or "aulds" which doubtless did good service at one time in sewing fur garments for the ancient Briton.

There is a considerable similarity between the jaw of a pig and that of the genus *Homo*. During the exploration, a person who assisted me picked up a bone, and observing him standing and looking at it with a mixture of curiosity and dread depicted on his countenance, I said, "What is this you have got hold of now?" His diagnosis was decided, as he at once replied, "a tremendous man's jaw." It was that of a pig!

I have heard it said that Professor Huxley at one time described a number of bones from a shell-mound somewhere in the north of Scotland, but I do not know in what publication his remarks on the subject are to be found.*

* Since the above was written I have had a note from Professor Huxley to say that he is not personally responsible for the cannibalistic theory mentioned in the paper referred to.

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No. XXX.—On the Modern Manufacture of Ancient (?) Flint Implements, including an Interview with an Irish "Flint Jack." By James Neilson.

[Read 14th April, 1892.]

On two occasions last year business took me to the north of Ireland, where I utilised my spare time by visiting the Giant's Causeway and the district adjoining. On the first occasion I went by rail from Londonderry to Portrush, an enjoyable ride, during which most interesting views were obtained of the Antrim chalk cliffs with their basaltic caps. This most characteristic feature of the coast line of N.E. Ulster was best seen at Downhill and Castlerock, while the great Atlantic breakers, from a recent storm, rushing shorewards and bursting in snowy whiteness on the sandy beach, presented a scene of beauty hardly surpassable.

At Portrush we were transferred to the electric tramway car, having 8 miles still to go before reaching our destination. For the first 2 miles we skirt hills of blown sand, and then reach the exposure of strata known as the "White Rocks," the equivalent of the English chalk, and overlaid by basalt which has burnt them nearly as hard as itself. These "White Rocks" form a continuous series of sea-cliff for some miles, and appear to be from 60 to 100 feet in height. The action of the sea has worn them into extraordinary shapes, and a Scotchman may here see in a couple of hours as many rock arches as he would in a lifetime in his own country.

On a black cavernous rock, adjoining a fault which cuts off the chalk, stand the picturesque ruins of Dunluce Castle, with its narrow approach, and its buildings bearing a resemblance (when seen from a distance) to the well-known Dunottar Castle, near Stonehaven, on the Aberdeenshire coast. From this our road now becomes more tame as it runs inland, and shortly we arrive at the Giant's Causeway, the terminus of the car line.

On my second visit, starting from Belfast, we took rail to Larne, from which the journey was continued by means of long cars along the coast road as far as Cushendall, about 25 miles distant, thence inland over a mountainous road to Ballycastle, 16 miles, whence another drive of 13 miles brought us to the Giant's Causeway. By taking the electric car to Portrush, and rail to Belfast, the circle may be completed in an agreeable trip of two days.

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On the Antrim coast road the scenery is sometimes magnificent, the great chalk cliffs with their basaltic covering being very impressive. In some cases we observed basaltic columns as large in diameter as those seen in Cathkin Quarry, while far surpassing them in length. At other places the occurrence of the Lias could be detected by its peculiar habit of breaking away from the main cliff, and forming an undercliff sometimes a mile long. Owing to this same habit of the Lias the roads even frisk about in a manner that would be positively dreadful in the eyes of our staid, old-fashioned roads at home.

At intervals, relieving and breaking up the long line of cliff, we pass the beautiful bays of Glenarm, Carnloch, Red Bay, Cushendall, and Whitepark, and the famous "Glynns" or glens of Antrim—foremost among which we have a splendid view of Glengarriffe, the queen of them all. From Ballycastle may be had a view of the magnificent headland of Fair Head, nearly opposite the Mull of Kintyre, while parts of the Scottish coast from Cairn Ryan to Islay are visible. This locality formed the ancient home of the Scots or Dalriads, and from here they crossed over to Cantyre, gradually making themselves masters of the country, to which they afterwards gave their name—Scotland, or the land of the Scots. We pass the old castle of Dunseverick, which is still pointed out as their chief seat, while under our eyes is the island of Rathlin, in which King Robert the Bruce found refuge during his time of adversity. Anyone who has taken this route will admit that it forms one of the finest and most enjoyable excursions to be found anywhere.

The geological formations brought under review during the journey may be classed in descending order as follows:—

Tertiary Basalt.	
Chalk, Greensand, Liassic Beds,	most of the way.
Triassic Rocks,	at Carrickfergus, Red Bay, &c.
Carboniferous Rocks,	near Ballycastle.
Old Red Sandstone,	near Cushendall.

It has been remarked that Arran is an epitome of the geology of the world, though the newer formations are not found there. From the above table it will be seen that Antrim fills up the gap. In strange contrast to Arran experiences, however, we are told that there are no dikes in Ulster.

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Before entering on the more particular subject of this paper I must not omit to notice a visit to the rope-bridge of Carrick-a-rede. Situated amidst wild and grand scenery, and crossing a chasm some 60 feet wide and as many deep, the first sight of this bridge, as I saw it, was well calculated to take away one's breath. Two ropes stretched across the chasm supported a series of light wooden spars, on which a single 9-inch board formed all the footing, while, on one side only, a rope served the purpose of a hand-rail. The weather being stormy the bridge swung alarmingly, and my first feeling was not to attempt it, but, after waiting for some time, I came to two conclusions—first, that the bridge would not blow away; second, that I could hold on to the rope. For the first few steps I was all right, but near the centre a sudden squall set the bridge shaking so much that I had to stop and hold on tenaciously till it steadied. On reaching the island we found the fishermen were about to return, as they could not work on account of the storm. It was rather gratifying to my overstrained nerves to find that they waited for the wind to moderate before crossing to the mainland.

I shall not here attempt any description of the Giant's Causeway, but merely remark that though it may be seen from the sea or from the top of the cliffs, by far the most impressive view is to be obtained from a footpath which runs along the face for about 2 miles east of the Causeway proper. The guides try to frighten strangers by saying that the path is unsafe, but it is really not so, as the dangerous parts have been cut so as to render them safe for the passage of sheep. No guide is actually necessary, but I took one—Charles M'Allister by name—an obliging fellow and a good climber, who showed me the quarries opened in search of minerals. I could not but express my astonishment at their extent, and the dangerous positions in which many of them are situated. We climbed up together to one on the top of a sharp ridge of rock called the "Horse's Back"; and, however it may be with other articles sold at the Causeway, there is no doubt that the minerals represent good, hard, honest work, which deserves encouragement.

On my first visit (in spring) I was offered for sale numbers of flint arrow-heads, everybody having some to dispose of, and, there being at that time of year few tourists and little demand, prices were low. I bought a selection, but being rather suspicious of

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the quantity for sale, I questioned everyone likely to be able to afford any particulars regarding them—guides, quarrymen, hotel folks, and visitors. In this way, bit by bit, I picked up a considerable amount of information, of which I now propose simply to give the result.

In the manufacture of flint implements the flakes were chipped off a round or many-sided flint nodule, row after row reducing it gradually till it was too small for further chipping, when it became a "core." In each flake the dividing ridge between the two flakes which had been chipped off immediately above it became the centre, so that it was thus somewhat thicker at its centre than at its edges. In some parts of the country such flakes, genuine remains of the old manufacture, are quite common. Probably the finer specimens only were selected to be fashioned into implements, the others being thrown aside. Another common implement is known as a "thumb scraper," as it is supposed to have been held between the thumb and forefinger when used to scrape the skins of animals in the process of curing, or to scrape down wooden articles.

I carefully examined a considerable number of the stone and flint implements offered for sale at the Giant's Causeway, and I was of opinion that, with the exception of the flakes and scrapers, I did not see a single genuine specimen; but that, like the cheap razors, they were one and all made to sell. Perhaps from this should be excepted one or two stone celts (not flint) and one stone hammer, which I thought might be genuine.

As was probably the case in olden times, celts and hammers are now made by grinding and boring stones selected from the beach for their resemblance to the required shape. So well are these articles now fashioned that it is impossible for an inexperienced eye to tell the difference, and even the best authorities are sometimes deceived. One lady told me that she had seen a gentleman (who shall here be nameless), considered to be one of the best judges of such matters, reject a flint arrow-head which she knew to be genuine, and accept another which, "with her own eyes," she had seen made shortly before.

Several persons in this neighbourhood were said to be manufacturers of flint implements, but all my informants united in awarding the palm to one man who was expected to come to the Causeway

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on the following day, but who, much to my disappointment, did not turn up.

He was reported to make a good bit of money by his manufacture, but, unfortunately, could never keep sober if he had as much in his possession as would enable him to get drunk.

On the occasion of my next visit I made further enquiries regarding this individual, but at first could hear nothing more regarding him. However, on leaving the hotel in the evening we were followed by a tall, thin, gaunt-looking man, who accosted me with, "You were axing for me, sorr. I'm so and so" (mentioning his name, which I had previously heard). "Oh," I said, "are you the man who makes the flint arrow-heads?" He was, or pretended to be, surprised at my question, but finding I was well informed about the matter he no longer attempted concealment. I was therefore much pleased to find that I had at last got hold of the right man, and that I could get him to speak out, as I understood him to be the most famous "Flint Jack" in Ireland.

He gave me a long story about how his flints were to be found in all the museums and best private collections in the country, but, I presume, a considerable discount may be allowed for the "blarney" which springs naturally from the soil. He was very anxious to sell me a stone hammer which he confessed to having made himself, but I said that the only things I would buy from him would be flint arrow-heads actually made in my presence. At first he made some excuses about not having anything to make them with, but I gripped his jacket, and turning the edge told him he had something sewed on there for making them. On seeing that I was up in the particulars he unbuttoned his waistcoat and exposed a piece of strong leather sewed on inside, and then taking from his pocket some flint flakes he selected one and proceeded to form it into an arrow-head, using as a tool a pointed piece of basalt, and remarking that any stone hard enough for road metal was sufficient for his purposes. Holding the flake between his left thumb and forefinger, he pressed the point of the basalt against its edge, breaking off little chips and turning it over and over as he gradually worked it into shape, simply by pressure, the leather serving as a guard for the protection of his thumb. In the space of about four minutes he produced a barbed arrow-head, which would be not only quite suitable for its purpose, but which

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might very well be mistaken for a genuine specimen of an ancient one. He also made various others during our interview. One thing which surprised me was, that he reserved the thickest part of the flake for the point of the arrow-head. I had been informed that he used a key to shape heavier flakes, but I did not see him do anything with such a tool.

In striking off the flakes from the mass he said that a stone did much better than a hammer, though, not having ocular demonstration, possibly this was said to please me.

Some of the arrow-heads had a green coating, which, like the verdigris on bronze, made them appear more ancient, and this, he said, was obtained by rubbing the specimen on a "docken." Stone hammers after being made were burned in a peat fire to give them a brown, old look.

I may say that I have tried to make some arrow-heads myself, but the flakes I had were not of the thinnest, and I discovered that the left thumb required a strength of muscle which mine had not got, and which, I presume, would take a considerable amount of practice to develop.

I believe this man does a lot of his preparatory work at Bushmills old quarry on the way to Portrush, where, by the way, he told me there are plenty of fossil sea-urchins.

This enterprising individual's manufactures did not end with stone hammers. He was very anxious to make me an urn, which, however, would take two days, but would, he said, be undistinguishable from an ancient one, and the cost would be five shillings. He did not obtain an order from me, but I afterwards saw some baked clay urns offered for sale at this price, and I have no doubt these had a similar origin. I believe that more of the same kind may still be had by any member of the Society who is desirous of possessing an undoubted specimen of the "rale genuine ancient urn"—of modern manufacture.

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No. XXXI.—A Visit to the Island of Little Cumbrae, with some Notes on its Minerals. By James Neilson.

[Read 12th April, 1892.]

Although the Island of Little Cumbrae must be perfectly familiar —by sight at least—to every member of the Society, I am afraid that only a few have ever set foot on its lonely shores. This arises not so much from its comparative inaccessibility as from a mistaken notion that, amid so much surrounding beauty, the "Wee Cumra" is hardly worth a visit. It will, however, be found that the rocky island has charms all its own, and differs so much in almost every respect from the other Clyde islands and from the neighbouring mainland that it may, as a whole, be described as unique.

The lover of the lonely who walks its shores or glens may here indulge to the full his feeling of *monarch-of-all-I-survey-ishness.* For the archæologist there are prehistoric remains — early Christian church ruins and graves; the foundations of what is said to have been a round tower; cairns supposed to have been raised over Norse warriors slain in the battle of Largs; an old castle of historic times; and an old lighthouse perched on the summit of the hill. Several of the caves are believed to have been at one time inhabited, and in a rocky recess on the shore near the northern point is what I take to be the remains of an ancient kitchen-midden yet awaiting exploration.

Nor is the interest afforded by the Little Cumbrae less to the geologist. Its terraces present possibly one of the best examples of that stair-like appearance from which the name *trap* is derived, the various overflows of igneous rock rising over one another and breaking off sheer at their edges. There are several varieties of trap, some being amygdaloidal, while others, comparatively compact, contain large cavities lined with various minerals. Some of these cavities are as much as a foot in diameter, and are lined with a peculiar milky variety of quartz from 1 inch to 2 inches in thickness, the insides being apparently entirely empty. The inner surfaces of this lining present large mammilations closely covered with small crystals.

Many other cavities found in these rocks are filled with calcite or various kinds of zeolites, including analcite, white

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stilbite, and red heulandite. Localities for this latter mineral—heulandite—are now almost unknown in the West of Scotland,* and it is therefore interesting to know of one station where it can certainly be found. The visits I have paid to the island have been too short to enable me to thoroughly examine all the rocks, but I have found heulandite among the stones on the beach about half tide, at the northernmost point of the island, Sheannawally Point, although not *in situ*. It is, however, common at Gull Point, the most southern point of the island, where it may be got amongst fallen rocks on the beach, or *in situ* in the rocks of the cliffs above. The specimens I have found are all more or less weather-worn, and so do not show the crystals to advantage, but if the rock were quarried doubtless fresh specimens could be obtained. Cluthalite, which was originally described as a separate species by Thomson in his "Outlines of Mineralogy, &c.," 1836, is found here in abundance. It is now included in the species Analcite, and is not even mentioned either as a variety or a synonym in the "Catalogue of Western Scottish Fossils," 1876, nor yet in Dana's "Manual of Mineralogy." "Reddish white" is the nearest approach in Dana's description of analcite to the colour of cluthalite; it is better described by the "flesh red" of Thomson. As it is apt to be mistaken by the student who is only familiar with the ordinary varieties of analcite, it seems to me that it would be more convenient to retain the old distinctive name. Small specimens of chalcedony are also found here, though rarely.

If the weather is calm the visitor to the island may leave his boat among the rocks opposite Gull Point, but if there is any swell on the water it is better to land at the bay near the old castle and walk. Although there is hardly a footpath even, and the road is both rough and occasionally wet, still there are many objects of interest to repay the trouble. You walk along the level terrace of the old Raised-beach under the rocky cliffs, some of them very fine, and pass within sight of the Split Boulder figured by Mr. Smith of Jordanhill, in his well-known work.† After some time we come to a place where the Raised-beach terminates, and the cliffs come down to the sea. These rocks are traversed by

* See paper by Dr. Forster-Heddle in *Transactions*, vol. ix., part 1, p. 72.

† "Researches in Newer Pliocene and Post-tertiary Geology." 1862.

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several dykes which have been cut out by the waves, leaving narrow passages 30 or 40 yards long by as much, sometimes, as 20 feet deep and 2 or 3 feet wide, through which we continue our way.

Gull Point itself is a high rocky point, approaching so close to the sea that there is only room for a narrow pathway between it and high tide mark; while high up on the face of the cliff there is a beautiful rock-arch. Under this the zeolites may be found in detached fragments on the beach, while immediately round the end of the point they may be found in a more compact rock *in situ*.

The walk may be continued along to the New Lighthouse, where the cliffs are higher and more impressive. Several large caves are passed on the way. If the boat has been left near the castle the return journey may be made over hill, with a visit on the way to the Old Lighthouse on the highest point of the island.

In any case the visitor should not leave without seeing the solitary graveyard on the top of the cliff two or three hundred yards west of Gull Point. It is somewhere about 4 yards square, and originated in a girl desiring to be buried there. The story is that when her sweetheart went to sea, she came every day and sat on this cliff to get the earliest glimpse of his returning ship; but hope deferred made the heart sick—she pined away and died, leaving as her last request that she might be laid to rest in this lonely spot. I am afraid, however, that the early age recorded on her tombstone renders this story more than problematical.

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No. XXXII.—The Geology of the Carsphairn District. By David Forsyth, M.A., D.Sc. With Two Plates [Nos. XIV. and XV.]

[Read 14th Jan., 1892.]

I. *General Description of the District.*—The parish of Carsphairn forms the borderland between Ayrshire and Galloway, and consists of the upland valley of the Deugh, flanked on each side by mountains—the highest in the Southern Highlands of Scotland. This mountain district may be regarded as supplying the head waters of the Ken, which flows in a generally southern direction till it enters Loch Ken. On leaving Loch Ken it is joined by the Dee, which in turn gives name to the united streams as they pass on to Kirkcudbright bay. The district can be reached, therefore, in two ways—by New Galloway and Dalry from the south, and by Dalmellington from the north, about 10 miles distant. The latter route is the most frequented, if we can use such a term for roads in such mountain solitudes. The road from Dalmellington to Carsphairn is of great geological interest, as from it may be seen good sections of the three great formations of Southern Scotland —Carboniferous, Old Red Sandstone, and Silurian—it therefore merits a brief description.

On leaving Dalmellington the road follows one of the numerous tributaries of the Doon; and the traveller is soon interested in the well-preserved "moat," and in the numerous sections of sandstones, shales, and thin-bedded coals, so characteristic of the Carboniferous formation. Two very good examples of the displacement and alteration of strata by one of those dolerite dykes, so common in this coalfield, also occur on the roadside and in the adjacent burn.

Soon is reached the region of the Calciferous Sandstone, where the strata are manifestly uptilted towards the S.E. against the southern mountain ridge—that sinuous line of elevation which stretches across Southern Scotland, and in this district always gives two drainages, the one N.W. and the other S.E. Although the point of immediate contact is concealed by the alluvial débris of the stream, the observer notices at a very short distance a complete change in the strata; reddish coloured or purplish flags, and rudely stratified conglomerates take the place of shales and sandstones, and the dip of the beds is towards the S.E. Evidently this is the line of the great fault which separates the Old Red

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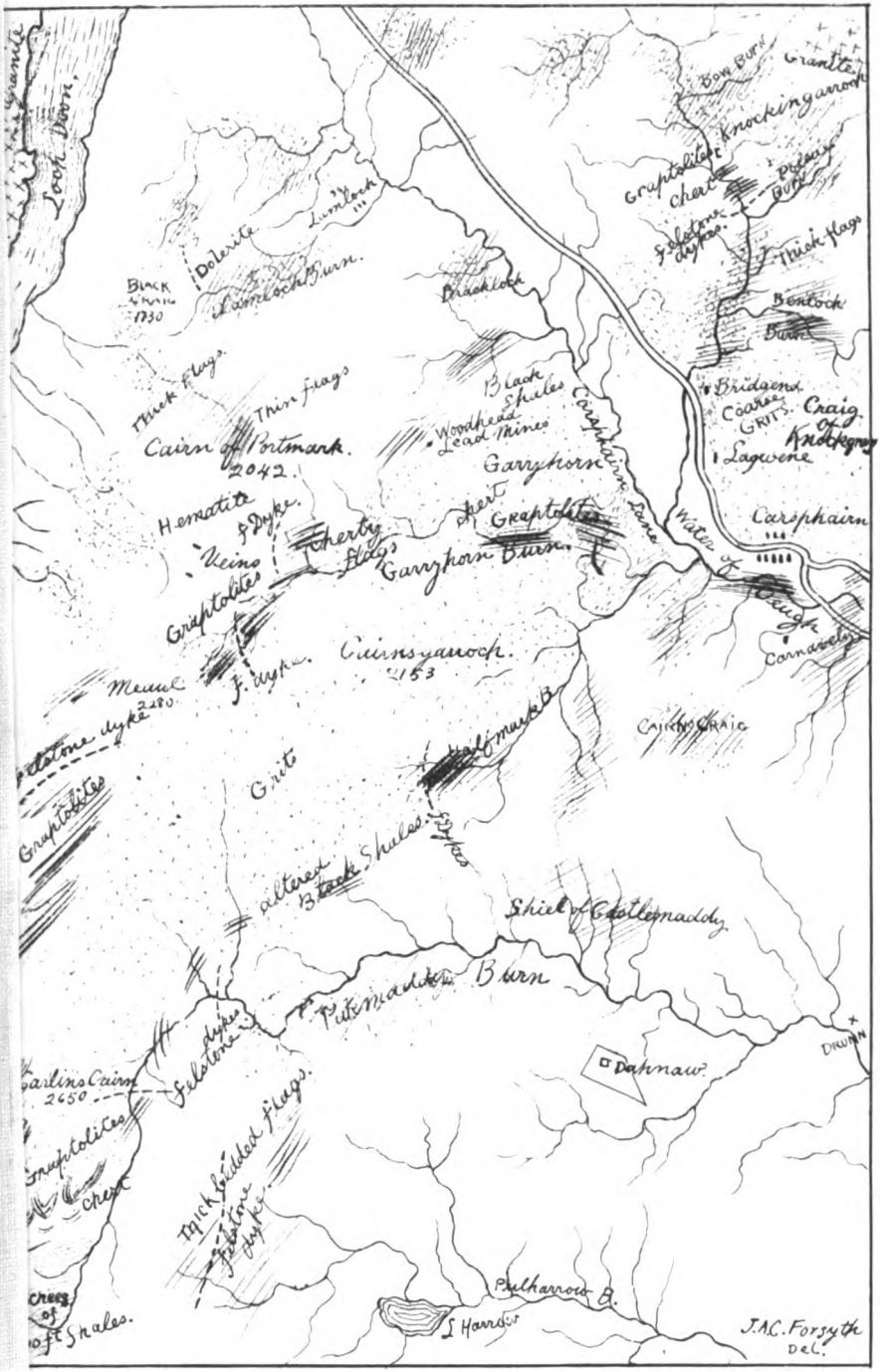

TER & PRATT, LITH.

MAP OF CARSPHAIRN DISTRICT.

Scale 1 in. = 1 mile.

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Sandstone on the N.W. from the Ayrshire Carboniferous strata of Girvan and Straiton; just as a second fault separates the Old Red Sandstone from the southern Silurians. Numerous porphyritic and felspathic beds are interbedded with these sandstones, and in a few places are to be seen instances of the metamorphic action of those intrusive pink felstone dykes so characteristic of this southern area. In three places, also along the side of the burn, are found thin veins of hematite, staining the surrounding rocks, and discolouring the water. These veins seem to lie along the *dip plane* of the strata—a method of occurrence which will be mentioned again when I speak of the Silurian area. These rocks have yielded me no fossils, as, although some thin-bedded mudstones did look likely localities, they proved most disappointing in results.

A still greater change soon awaits the traveller. About 3 miles from Dalmellington the road passes through quite a mountain gorge with steep escarpments on each side, the strata consisting of grey-blue flags, with an outcrop from S.W. to N.E., and an inclination, sometimes of 60°, to the S.E. They have all the external characteristics of the southern Silurians; and possibly the gorge was first hollowed out from the higher grounds to the south by ice, and then by the subsequent action of running water the ravine was deepened. All the rock-surfaces from which, by any chance, vegetation has been recently removed give evidence in grooves and striæ of glacial action. As the burn crosses the strike nearly at right angles many excellent sections are seen, but the absence of fossils prevents any systematising of the strata; although there are not wanting many physical evidences that the thickness of the formation here is not so great as one would suppose, but that the sections are rather repeats, by contortion and plication, of the same strata.

On gaining the top of the ridge, between the road and Loch Muck, glacial striæ on the surface of the projecting knobs of ground are seen, their general direction being to the N.W. or N.N.W. The loch itself has all the appearance of an ice-scooped basin, partially filled by debris and vegetable growth. From the side of the loch is obtained quite a panoramic view of the southern mountainland, and the great hollow occupied by Loch Doon (although the loch itself is not visible at this point), flanked on each side by massive mountains, such as Meaul and Carlin's Cairn,

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and in the distance by Merrick, the highest summit in Southern Scotland.

After passing the crest of the watershed the drainage is towards the south, the principal stream being the Carsphairn Lane, a sluggish stream which "winds its weedy way" till it joins the Deugh; and, although at a few places shales are seen, it exhibits no striking sections in its whole course. Yet the valley is not without points of geological interest—moats, as the "Strife Moat" at Lamford (where, tradition says, disputes used to be settled by appeal to arms), at Brockloch, and Daltallochan; and also kames and moraines. The ridge at Cadger's Hole projects across more than half of the valley, and seems to have dammed back an old loch, whose waters afterwards breached the mound.

The contour of the country leads me to think that such mounds are mostly due to the excessive denudation following the glacial age—that in fact they are "rubbish tips" made by tributary streams. Nor should one forget the pleasing contrast of Lamloch—like a fairy dell in the midst of the lone wilderness—a little nook in which are gathered all the floral treasures of the district.

As we approach the village, the Deugh is crossed by a picturesque bridge, near which the thick-bedded blue-grey flagstones and massive grits present a striking contrast to the scenery of Carsphairn Lane. A fine avenue of old trees opens up the first view of the village, seen nestling at the foot of the hills, and the weary traveller soon finds a welcome at the hospitable Salutation Inn.

II. *Special Description of the District.*—Carsphairn is a small, clean village of one street, lying cradled amongst hills. As already stated, the joint valleys of the Deugh and Carsphairn Lane notch the hills by a trench-valley running from north to south, while to the east and west the hills rise rapidly from the village. To the east the craig of Knockgray rises to the height of 1250 feet, affording a fine view of the whole district; and behind it, still further to the east, in a series of grand swells, towers the mighty mass of Cairnsmore of Carsphairn (2612 ft.), so called to distinguish it from its lower rivals of the same name, Cairnsmore of Dee and Cairnsmore of Fleet. West of the village street is an alluvial flat, composed of large gravel washed down by the Deugh and its tributaries; while immediately west of the Deugh the ground begins to rise rapidly into a series of secondary ridges—

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Cairnsgarroch (2153 ft.), Craigneldie (2000 ft.), and Craigrine (2000 ft.). Again these are backed to the westward by the mighty rampart of the Kells range, where the prominent summits are Coran of Portmark (2042 ft.), Meaul (2280 ft.), Carlin's Cairn (2650 ft.), and Corserine (2668 ft.), overlooking the deep trench in which lies the rock-basin of Loch Doon. On each side, also, of the Carsphairn valley there is a granitic boss—Cairnsmore to the east—and another, to the south-west of the Doon valley, stretching from Craigmalloch to Merrick—the mountain nucleus from which spring the Girvan, the Stinchar, and other streams. Between these two bosses the strata are grits, flagstones, and shales, their strike being generally from S.W. to N.E. These abut in their course against the granitic masses without much deflection or contortion, and on the other side of the outburst resume their usual direction and monotony of structure. The granitic bosses seem, therefore, either to have been volcanic "outblows" through the older sedimentary strata, or, perhaps with greater probability, volcanic intrusive masses from which subsequent denudation has removed much superincumbent material. Such outbursts have of course produced much change in the adjacent rocks, but the metamorphism is very varied in amount and in kind

One type is well illustrated round Cairnsmore, where the whole of the strata immediately surrounding the central mass are altered by what might be termed *contact* metamorphism, so that sandstones and conglomerates become altered into quartzites, and mudstones become hornstones or lydianstones. But this metamorphism is not always uniform, for I have often traced Silurian flagstones close up to the granitic boss without noticing much alteration, and in many cases no change is apparent at 100 yards from the igneous rock. Nor yet is the metamorphic area so large as one would expect from so great a granitic nucleus, for it seldom extends a mile from the granite.

Another type of rock-metamorphism is seen in the influence of the numerous felstone dykes which intersect the sedimentary rocks in all directions throughout this area. These dykes can be traced like fingers, stretching out from the granitic centre altering on each side the character of the aqueous rocks, and giving them not only a hardened crystalline character, but entirely changing their appearance and mineral structure. One area of grits on the

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W.S.W. side of Meaul looks more like a micaceous schist or gneiss than a grit, from the prevalence of a black-brown mica amongst the crystalline matrix. Indeed, I have fallen into the habit of calling them *granitoid grits*, as best expressing the internal structural change which has been produced.

These black shales afford excellent examples of a third kind of metamorphism. From contortion, pressure, and heat-contact they are so altered that in some districts they cleave into blocks like basalt; in others they have the appearance of a black dolerite, with grains of quartz; while in others, from possibly the destruction of graptolitic remains, they have the shimmery, scaly appearance of graphite.

III. *Geological Structure of the District.*—In such a district as this, where, at first sight, the sedimentary rocks present a remarkable monotony of appearance, suggestive of no arrangement, and of enormous thickness of deposit, there are but two guides to an intelligent understanding of its geological structure—(1) the following out of a formation easily recognised and fairly persistent; and (2) the mapping out of the fossiliferous beds. In this district the grits supply the first or lithological index, and the black shales or graptolitic shales the second or palæontological test. The Carsphairn grits extend in a general S.W. to N.E. direction from Carlin's Cairn, by Cairnsgarroch and Knockgray, to the shoulders of Cairnsmore, forming in contour two oval-shaped masses, connected by a narrow isthmus of alluvial land. The graptolite shales are closely connected with these grits—often appearing to come from below them, and always following them in endless sweeps and curves through all the variable surface conditions of height and hollow. [See Plate XIV.]

The Deugh and its tributaries cut across the general line of strike at varying angles, and this, along with the twistings of the strata themselves, render the mapping of the district a task of extreme intricacy, and often of a misleading nature; while the tracking of the graptolite beds often leads one down into deep dells, and then to the crests of ridges fully 2000 feet above sea-level. But the ever-varying prospects, the sweet nooks, as at Lamloch and in Half-mark Burn, the refreshing breezes, and the successful finds, are ample compensation for the toilsome climbs and the drenching showers of this upland country.

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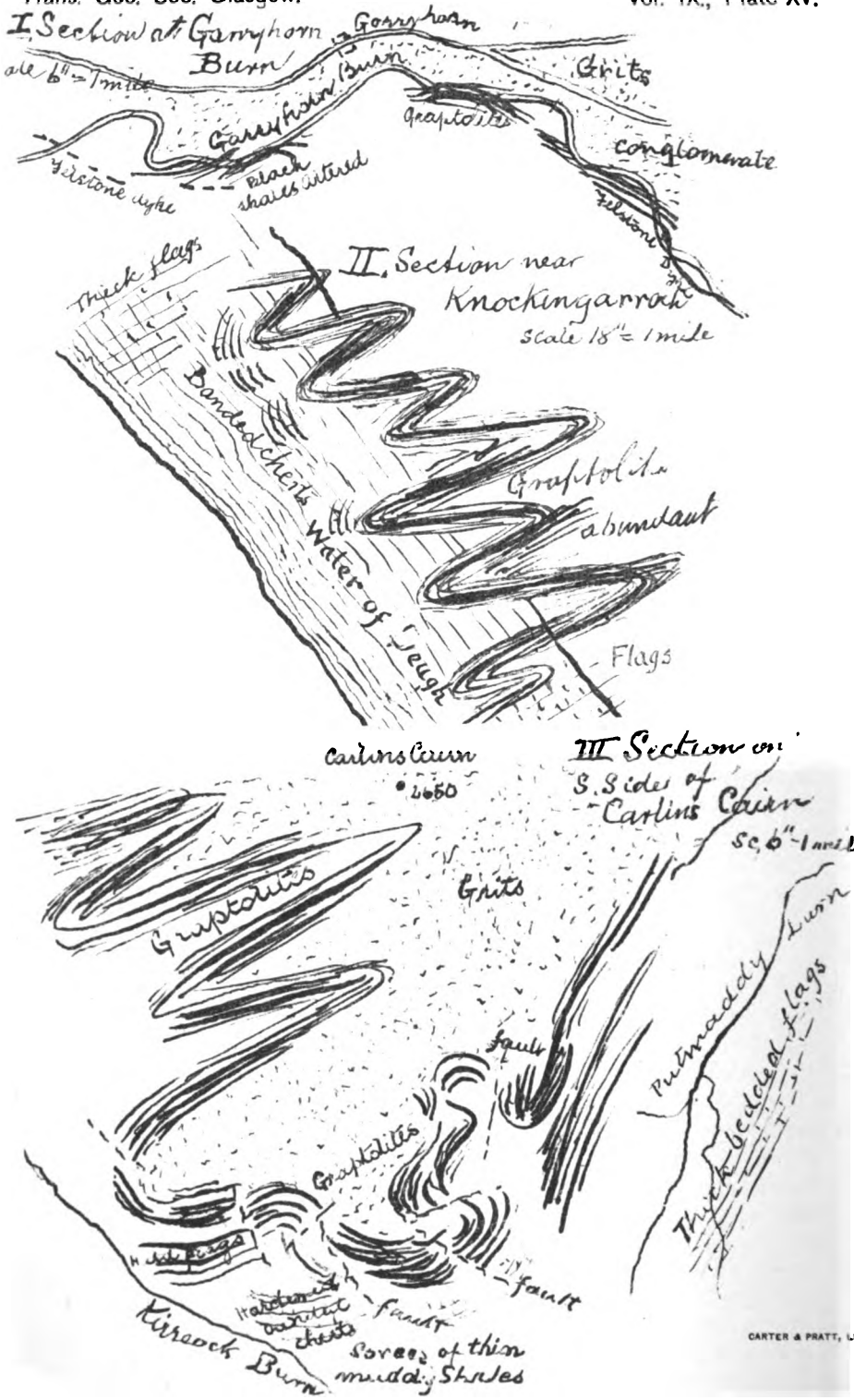

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IV. *Sections.*—A. *West of the Deugh and Carsphairn Lane.*—One of the nearest sections to Carsphairn is that shown in Garryhorn Burn [Plate XV., section 1], and in some of its features it is quite characteristic of the structure of the country. At the foot of the burn, near its junction with the Deugh, are found flagstones and grits. At the first footbridge occurs a conglomerate, which at some parts exhibits a brecciated structure. Further up the burn occur black shales, much altered and glittering like graphite, often containing iron pyrites, but no fossils. On the opposite bank of the burn the same shales are less altered, and graptolites are found, being succeeded to the left by thick flags, which dip beneath them at 60° to the N.E. A felstone dyke, seen here in the bed of the burn, accounts for the metamorphism of part of the shales. Above the Garryhorn farmhouse the felstone dyke appears again in the bed of the burn, and is here bounded on both sides by black shales, altered to hornstone, but with no fossils. The felstone is in some parts compact and crystalline, and in others quite earthy, with lenticules of shale included. At a still higher point in the burn the shales are so altered as to break under the hammer in square blocks like jaspery lydianstone. This section seems to indicate that under the grits and conglomerates runs a bed of black shale with the thick flags below it. The graptolites found here are :—

Lasiograptus costatus, Lapworth.
Dicranograptus ramosus, var. *elongatus*, Lapworth.
Didymograptus superstes, Lapworth.
Dicellograptus sextans, Hall.

B. *Cairnsgarroch Section.*—For a long distance after this the Garryhorn Burn passes over marshy, alluvial land, in which the superficial covering hides all sections. To the right, however, are the ruins of the works where, at Woodhead, lead was mined ; and among the débris I constantly found specimens of black shales, but with no fossils. Among the same heaps I found specimens of elvanite, syenite (or granite, in which hornblende replaced mica), and on the sides of the Bow hill many boulders of syenite lie scattered.

In the Garryhorn Burn, above the waterfall, is a very interesting section ; a felstone dyke, which crosses the burn twice, alters the grits into a kind of *granitoid* rock, and the shales into bands

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of flinty hornstone. In this section the black shales lie N.E. of the grits, and are succeeded by thick-bedded flags. The same black shales can be traced in two or three projecting hummocks on the face of Bow hill, at a height of 1600 feet; but they are much altered and contorted, and have no graptolites. A very fine section is found on the steep N.W. face of Cairnsgarroch, about 1800 feet above sea-level. The upturned black shales have an outcrop from S.W. to N.E., and dip below the grits at a very high angle towards the S.E. The shivered débris forms screes down the steep mountain side, sometimes rendering the footing dangerous, but the abundance and variety of the graptolites are ample reward for the risk. The forms most commonly found are:—

Didymograptus superstes, Lapworth.
Dicranograptus ramosus, Hall.
" " var. *spinosus*, Lapworth.
Pleurograptus linearis, Carruthers.
Climacograptus bicornis, Hall.

The succession here is the same as that in the Carlin's Cairn sections (to be afterwards mentioned); but this area is remarkable for the metamorphism in some parts. Some specimens of grits are quite granitoid, and the thinner flags are altered to jaspery hornstones. Nor should mention be omitted of three or four openings which have been made for hematite in the southern and western slopes of Bow. The hematite seems to occur in thin veins along the plane of the bedding of the flags, and the openings are made along a ridge about 1900 feet high.

The magnificent panoramic view obtained from this ridge cannot be passed without remark. The spectator, 2000 feet above sea-level, stretched on the short wind-swept heather after his steep upward climb, rests his eyes on the wide prospect, as I did on my last visit, when Loch Doon

"In all her length far winding lay
With promontory, creek, and bay,
And islands that, empurpled bright,
Floated amid the livelier light,
And mountains that like giants stand
To sentinel enchanted land."

Beneath my feet lay the long expanse of the loch, with its islands seen from that elevation, *almost in plan*, and with the old castle mirrored in its calm waters. Towering in front rose Merrick and

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Shalloch, blue in the distance, with the gleamings from the waters of Loch Macaterick and Loch Finlas lighting up the dark hollows. To the geologist the map-like picture of the effects of denudation —seen in the hummocky hills, and in the rock-basin lochs—was a profound and suggestive lesson. From this height the contrast between the two sides was most marked, the trench-like valley, occupied in part by the loch, but extending also considerably further south, seemed to form a line of division between two different rock-formations, which had been acted on by one and the same agency.

C. *Meaul and Carlin's Cairn Sections.*—Following the long narrow ridge between Bow and Meaul I found abundant shivers of graptolitic shales immediately to the west of the summit of Meaul and about the level of 2000 feet. The shales had the usual strike, from S.W. to N.E., but the specimens, owing to the small exposure of rock, and the weathering to which they have been subjected at such a height, were not in good preservation. The principal fossils are :—

Pleurograptus linearis, Carruthers.
Diplograptus euglyphus, Lapworth.
Diplograptus quadrimucronatus, Hall.

Rather less than a quarter of a mile S.E. of these shales there occurs an altered grit presenting the most remarkable form of metamorphism that I have seen in this district. The structure of the rocks has been so much altered as to become largely crystalline, and the change has led me to speak of them as "granitoid grits."

Quite close to this place there is an extensive exposure of graptolite shales, due, I think, to quick flexures in the outcrop, whereby the apparent thickness of the strata is greatly increased. These shales continue to the south-west along the shoulder of Carlin's Cairn, keeping very much about the level of 2000 feet. There are few exposures of any great depth and the succession is therefore not easily made out ; but, from such as are visible, grits seem to extend along the whole ridge to the east, and thick-bedded flags towards the west of the black shales. The forms found amongst the shales include—

Pleurograptus linearis, Carruthers.
Didymograptus superstes, Lapworth.
Diplograptus quadrimucronatus, Hall.

To the south of Carlin's Cairn occurs one of the most remarkable

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sections of the whole district. The area embraces a semi-elliptical ridge immediately south of the cairn, and the exposures are such, on all three sides, as to show not only excellent sections of all the strata, but to indicate clearly their relation to each other. The grits occupy the hump of the ridge, and, sweeping round and between, with many a sharp flexure or more gentle contortion, lie the graptolitic shales; while to the extreme south of the semi-ellipse there is an exposure of banded or cherty flags, reminding one of the "calmy" shales of the Ardwell shore, near Girvan. This resemblance is still more remarkable from the screes, on the steep shoulder of Craigtarsen, which are composed of shivers of thin muddy shales, reminding one of the lower Ardmillan series of the same locality, south of Girvan. The steep ravine of the Pulmaddy Burn lays bare the entire succession—grits, black graptolitic shales, and flags. Graptolites occur in abundance all round the ridge, and fine specimens are obtained amongst the freshly-broken material of the screes on the sides. The shales are crossed by the Pulmaddy Burn, lower down, in three places; but only in one of the localities did I obtain graptolites. In the others the presence of a felstone dyke (of a beautiful pink where washed clean by the burn) accounts for the contortion of the shales and the absence of fossils. This dyke has all the look of a continuance of one near the head of the same ravine, which stands out in pink relief along the plane of stratification, against a high scaur of grey flagstones. The same altered black shales occur in the Goat Burn and Blaree Burn, with no graptolites, and with the accompanying felstone. Along the same line black shales occur in the small burns and drains, running down from the south-east of Cairnsgarroch, and also in the Pulterrson and Half-mark Burns, and always in the same relation to the grits; but in none of these localities have I found graptolites, even after a prolonged search. The thick-bedded flags to the south-east of the Pulmaddy ravine present no special features, except the grandly precipitous north-east face of Craignelder Gairy. The fossils found are:—

Climacograptus bicornis, Hall.
Diplograptus apiculatus, Lapworth.
Diplograptus Whitfieldi, Hall.
Dicranograptus Nicholsoni, Hopkins.
Dicranograptus ramosus, var. *spinosus*, Lapworth.
Didymograptus superstes, Lapworth.

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I am under the impression that this graptolitic band is continuous with the lower Garryhorn section, and that the upper Garryhorn and Bow sections are continued, greatly disturbed and contorted, and without fossils, towards Woodhead, along the S.E. face of Coran of Portmark, and that *somewhere* it crosses the Carsphairn Lane between Brockloch and Daltallochan. If such be the case, and scant and scattered evidences of black shales are found all the way, then this completes the survey of the district to the west of the Deugh, except a small patch immediately west of the schoolhouse, close to the water of Deugh, a manifest continuation of the Garryhorn section.

North of this area Coran of Portmark and Black Craig are composed of thick-bedded flags, with, at rare intervals, thin shales or flags. Overlooking Loch Doon, at the west side of Black Craig, are several large blocks of granite perched on the steep hillside at an elevation of 1400 feet. On the face of Little Craig is a dolerite dyke slightly altering the surrounding flags, which are again exposed in the pretty little dell of Lamloch. The black shales of the Woodhead section are continued in the Green Burn, a tributary of the Carsphairn Lane, opposite the farm house of Brockloch, but I have found in them no graptolites.

II. *Sections to the North and North-east of the Deugh and Carsphairn Lane.*—Immediately north of and behind the village is the rough circular mound-like Craig of Knockgray (1256 ft.), which is composed of coarse grits, more like those of Meaul than any others in this area. To the south-east, in the Knockgray Burn, are sections of thin flags and muddy shales; but in this direction I did not find any black shales, although I examined the ground very closely for the continuation of the shales of the Garryhorn and Deugh. Still further to the south-east lie the thick-bedded flags which, starting from below the Liggat Bridge, seem to extend in outcrop from S.W. to N.E. all over the hill-country of Dunool and Beninner; but, although sections are frequent in the tributary burns, and black shales interbedded among the flags occur at intervals, I could not find any evidence as to geological relation, nor as to whether the great apparent thickness from Liggat Bridge to Deugh was due to plication of strata or not. In this part felstone dykes are numerous and exercise the usual metamorphic effects on the circumjacent rocks. In Moorbrack and Furmisten

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the dykes are quarried and the boulders are utilised for curling-stones.

D. *Sections in Benloch Burn.*—West of Knockgray Craig, near Bridgend, there is a section of thick-bedded flags extending for fully 100 yards on each side of the bridge; and further up the Deugh are found beds of black shales, thin, contorted, and very much altered, glittering, like those of Garryhorn, with black carbonaceous particles, and with a good deal of iron pyrites diffused through them, but yielding no specimens of graptolites. In the Benloch Burn the same thick-bedded flags appear as in the Deugh; but after crossing the ridge there occurs a thick bed of black shales, a good deal contorted and much discoloured with iron, tilted on edge, with a general strike to the N.E. but dipping towards the S.W. This bed, from its position in relation to the neighbouring grits, seems to be the representative of the graptolite shales in Garryhorn, Meaul, Carlin's Cairn, &c., but after diligent search it yielded no graptolites.

Proceeding up the burn, grits, black shales, and thick-bedded flags succeed each other. Interbedded among the thick flags are occasionally thinner beds with thin black shales, and this succession continues up to the "black shoulder" of Carsphairn. As boulders in the bed of the burn banded cherty flags are seen, and their presence led me to expect a section similar to that of Carlin's Cairn, but I have not yet been able to trace them to their original position.

E. *Sections in Polsue Burn.*—The sections in this burn are similar to those in Benloch, black shales being succeeded by thin flags, and these again by thick-bedded flags as we proceed up the burn, but I did not find any graptolites. Towards the head of this burn an interesting junction of Silurian flags and shales with the granite of Cairnsmore is seen. The alteration in the aqueous rocks is slight until close to the granite, when they become much hardened; but the thin finger-like projections of granite veins into the flags present more variety, for not only are the thin flags and shales very much altered, but the character of this granitic vein is very much changed, losing its crystalline and assuming a more earthy nature, besides losing its special grey colouring and becoming a dull white earthy felspathic rock.

F. *Knockingarroch Section.*—On the Deugh, a short distance

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south of the shepherd's house at Knockingarroch, an excellent exposure of black shales is exhibited. The section [see Plate XV.], extends for about 180 to 200 feet, and although in that distance the bed is sharply flexured three times, graptolites are very abundant and in fine preservation, particularly close to the bank of the burn in the first and second curvatures. To the south this bed is succeeded by thick flags, which, at the junction of the Polsue Burn, are as hard and as resonant as dolerite. In the bed of the Deugh, immediately to the west of the graptolitic shales, are seen two small exposures of banded cherty flags. The graptolites found in this locality are—

Dicranograptus tardiusculus, Lapworth.
Dicranograptus ramosus, Hall.
Dicellograptus sextans, Hall.
Climacograptus bicornis, Hall.
Leptograptus grandis, Lapworth.
" *simplex*, Lapworth.
Lasiograptus bimucronatus, Nicholson.
Lasiograptus costatus, Lapworth.
Cœnograptus gracilis, Hall.
Cryptograptus bicornis.
Glossograptus Hincksii, Hopkins.
Didymograptus superstes, Lapworth.
Diplograptus euglyphus, Lapworth.
Diplograptus foliaceus, Murchison.
Cryptograptus tricornis, Lapworth.

To the N. and N.W. of this locality, drained by the Deugh and its tributaries, the prevalent strata are thick-bedded flags, sometimes merging into grits and conglomerates, and often crossed by felstone dykes; but I have met with no fossiliferous beds which would aid one to arrange the succession of these upturned flags, alike monotonous in their arrangement, colouring, N.E. strike and S.E. dip. They are evidently the same strata which, on the other side of Carsphairn Lane, form the mass of Coran of Portmark and Black Craig.

Summary.

My first conclusions regarding the district were:—1. That the thick-bedded flags to the north-west and south-east form the lips

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of a synclinal basin, and correspond to the Dalveen and Lowther beds of the north of Dumfriesshire; and here they are so thickened and so similar in appearance that it seems impossible to separate them. The great ridge of the Kells, including Coran of Portmark, Meaul, Carlin's Cairn, Meikle Craigtarsen, Craigrine, and possibly some of the other hills, are composed of these flags.

2. That basined in this syncline is a lenticular mass, or, it may be, masses, of grits, stretching from the summit of Carlin's Cairn, and Meaul, by Cairnsgarroch, Garryhorn Rig, Craig of Knockgray, and Dunool, to the side of Cairnsmore. The sections exposed in the western part of this elongated ellipse show clearly the succession, but the absence of characteristic graptolites in the black shales of the eastern part allows of a little dubiety. Still, when we consider the contorted character of much of this area, it is possible that repeated visits and more diligent search may enable us to place this area on the same footing of certainty as the other.

3. The shales which almost constantly come between the grits and the flags contain the characteristic graptolites of the Glenkiln series or Hartfell series.

But more careful consideration of the palæontological evidence afforded by the graptolites has led me to modify my opinions.

(1) From the constant occurrence of the typical Glenkiln and Hartfell graptolites in the same shales, and the absence of graptolites in other beds, it seems as if these two zones in the Carsphairn area come together without any intervening flags or sandstones.

(2) From the persistence of certain forms (*Didymograptus superstes*, *Dicellograptus sextans*, and *Dicranograptus tardiusculus*), one side of the shale bed seems to be Glenkiln, and the other side, from the prevalence of equally typical forms (*Diplograptus quadrimucronatus*, *Leptograptus simplex*, and *Pleurograptus linearis*), seems to be Hartfell.

(3) Under these circumstances the Carsphairn grits would occupy the central dome of an anticline, and form the lowest rocks of the district, corresponding possibly with the Barr conglomerates, and flanked by the newer Glenkiln and Hartfell shales, and these in turn by the thick-bedded Dalveen flags.

(4) The muddy shales of Carlin's Cairn and Knockgray are interpolated between the black shales and the flags and correspond to the Ardwell beds.

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(5) And the banded cherty flags which so regularly accompany the black shales may be the representatives of the Stinchar limestone. Perhaps another search along the shoulders of Dunool and Cairnsmore may give the same relations as occur at Carlin's Cairn.

The district of Carsphairn is one of great geological interest as one of the sources of the ice-borne granite blocks which dot the surface of south-western Scotland. But my notes on this and its other glacial phenomena I shall reserve until I can more thoroughly examine Cairnsmore, and the district between it and Cairnsmore of Dee, a wild region which I have had only once or twice a peep into, while the Merrick district must form the connecting link between the Girvan and Barr series and this Carsphairn area.

To all members of the Society I would urge the claims of a region, attractive in many ways; remote from the ordinary track, the traveller meets with thorough kindliness and cheap entertainment at the clean and hospitable village inns; the fisher enjoys ample scope for his gentle art; the botanist gathers rare specimens among the undisturbed solitudes; and one and all who visit this southern land of mountain and lake find, in healthful change, points of resemblance and contrast between it and its more majestic, and better known, but scarcely more picturesque, rival, the Northern Highlands of Scotland.

In concluding this paper I would like to express my indebtedness to Dr. Lapworth for valuable assistance in naming the graptolites of the district.

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No. XXXIII.—A Reverse Fault in Kiltongue Coal at Drumshangie Colliery. By Robert M'Laren, Inspector of Mines.

[Read 11th February, 1892.]

Reverse faults are of rare occurrence, and consequently in coming across one at the above colliery, I took notes with a view of bringing it before the members of this Society. The Drumshangie Colliery is situated to the north-east of Airdrie, in the county of Lanark.

The owners are Messrs. Drumshangie Coal Co., and the certificated manager is Mr. William Stevenson.

The extent of the field is 200 acres, and the Kiltongue coal is found in 120 acres; fully three-fourths of which has been worked. The field is intersected by a large throw of 40 fathoms, running south-east and north-west.

The Kiltongue coal lies in the upper coal measures, about 30 fathoms below the famous Airdrie blackband ironstone.

No. 1 pit, in the workings of which the fault was got, is sunk to the Upper Drumgray coal, at a depth of 46 fathoms, and Kiltongue coal in south section is reached by a cross cut mine.

The seam is worked longwall, with walls 14 yards long, and average inclination is 1 in 15.

A section of the seam is as follows :—

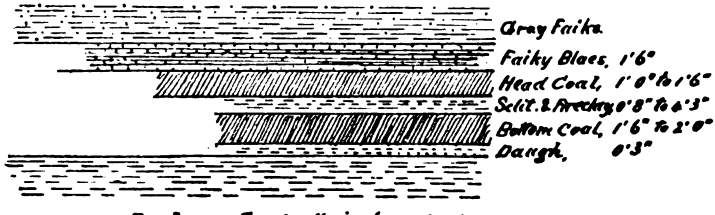

Fig. 1. Scale ½ inch = 1 foot.

In working the coal 20 yards from the large throw a hitch was met running north-east 60°. The side of the greater angle was lying off on the top, apparently showing an upthrow, but on cutting the "vees" it was found to be a reverse fault with a throw downwards. The hitch began at almost nothing, and where the throw was greatest it measured 2 feet. As it went to the rise it thinned off. The angle of the "vees" was small, being 30°.

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In coming towards the fault the rise was 5°, and inside it the rise was 14°.

The following section shows the position of the throw.

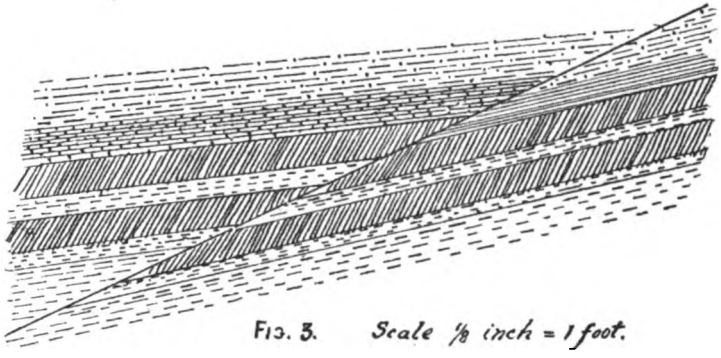

FIG. 3. Scale ½ inch = 1 foot.

Throughout the seam various disturbances have been met with in proximity to the large throw, and it is evident this reverse fault is due to the same cause.

The origin of reverse faults has recently been clearly demonstrated by Mr. H. M. Cadell in a series of experiments made by him, the results of which have been given in a paper read before the Royal Society of Edinburgh.* This paper with its experiments was also delivered by Mr. Cadell before this Society [see *Transactions*, vol. ix., part 1, page 228]. These experiments show that reverse faults are produced by horizontal pressure.

* "Experimental Researches in Mountain Building," by H. M. Cadell, Esq., B.Sc. *Transactions of the Royal Society of Edinburgh*, vol. xxxv. part 7.

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No. XXXIV.—Notes on the Geology of Fife. By the Rev. Alex. S. Wilson, M.A., B.Sc.

[Read 12th May, 1892.]

The county of Fife lies between the firths of Forth and Tay, and forms with Kinross a rectangle 36 miles in length by 14 in breadth. The total area of the two counties is about 600 square miles, and the coast-line extends to 85 miles. Through the middle of the county, for the greater part of its length, runs a hollow—the Howe of Fife, in the eastern half of which the river Eden flows, discharging itself into St. Andrews Bay. From Loch Leven the river of the same name issues, and after an easterly course of 12 miles falls into Largo Bay. Along the northern boundary to the west are the Ochil Hills, which are continued eastward as a ridge of moderate height between the Eden and the Tay, one of the peaks, Norman's Law, being 850 feet. North-east of Loch Leven are the Lomond Hills, 1713 feet; Largo Law, 1020 feet, is a conspicuous landmark on the bay of that name, and to the east of this Kelly Law rises to 800 feet. The Cullalo Hills, near Aberdour, attain a height of 750 feet, while the Cleish and Saline Hills, of similar height, are situated in the extreme west of the county. The surface of Fifeshire generally is undulating, exhibiting considerable variety, and the scenery in many parts is highly picturesque.

The geological map of Fife might be represented by a *tricolor* flag, the three horizontal bands corresponding to the three great formations of which the rock-strata of the county are built up. The northern strip is entirely occupied by great sheets of interbedded trap, variously designated whinstone, greenstone, felstone, and porphyrite. The middle belt of the county is formed of rocks belonging to the upper series of the Old Red Sandstone period. Loch Leven, Kinross, Strathmiglo, and Cupar are situated on this central area. The southern zone, which is the widest of the three, consists of strata belonging to the Carboniferous period, interrupted here and there by outbursts of igneous rock associated with patches of volcanic tuff and breccia. Taking them in order, we have the three bands running east and west:—

I. The northern zone of Interbedded Trap or Porphyrite.
II. The middle zone of Old Red Sandstone.
III. The southern zone of Carboniferous strata.

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I. The rocks of this northern zone are continuous with the traps composing the Ochil Hills, and form the eastern portion of the great belt of volcanic strata which stretches across Scotland from S.W. to N.E., through the counties of Renfrew, Dumbarton, and Stirling, into Fife. Known as the great trappean conglomerate, this belt includes rocks which belong to different ages. The trap rocks of Scotland have been formed at very different times—periods of intense volcanic activity alternating with long ages of inaction. During the early part of the Old Red Sandstone period the central district of Scotland was the scene of volcanic phenomena on the grandest scale. Miles on miles of country were deluged with fiery floods of molten lava, or buried under showers of scoriæ and volcanic dust—the Pentlands, the Ochils, and the Sidlaws being built up of successive sheets of consolidated lava erupted during this period. Then followed a long epoch of tranquillity, throughout which our Scottish volcanoes remained dormant, and the deposition of the stratified rocks of the Old Red Sandstone formation proceeded without interruption.

The succeeding age, to which belong the calciferous sandstones forming the base of the Carboniferous system, witnessed a renewal of volcanic activity. In this era the volcano of Arthur's Seat came into existence, throwing out the streams of basalt and porphyrite and showers of ashes which have formed the lower portion of that well-known hill. The traps of the Lennox and Kilpatrick ranges, the hills of Renfrewshire and North Ayrshire, the heights between Bathgate and the Forth, beds of tuff and porphyrite between Haddington and Dunbar, and possibly also similar accumulations near Burntisland, date from this time.

Above the calciferous sandstones lies the mountain limestone series. While the strata comprising this second division of the Carboniferous system were being laid down there existed numerous active volcanoes scattered over the central area of Scotland. During part of this period the greater portion of what is now Fife must have presented the appearance of an archipelago of volcanic islands, each fringed with its reef of coral, like groups of islands now existing in the Pacific Ocean. The eruptions became less frequent during the deposition of the millstone grit, and a period of comparative tranquillity succeeded, during which the true coal measures, forming the uppermost division of the Carboniferous system, were accumulated.

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Along the coast of Fife there are numerous isolated bosses, necks, and veins of trap, indicating that some at least of the volcanic cones of the Carboniferous period continued to manifest activity down into Permian times. The troubled condition of the coal strata furnishes conclusive evidence on this point. At the historical and far-famed Hill of Beath the trap has burst up through the limestone series, and the coal seams through which it passed are burnt for some distance round. The structure of the hill is that characteristic of a volcano; there is the central vent, containing a plug of lava encircled by beds of tuff formed of débris expelled from the volcanic orifice. The Lomonds, Largo Law, Kelly Law, and many lesser hills throughout the county also date in all probability from the time of the mountain limestone.

Early in Permian times volcanic action all over Scotland subsided; the masses of rock and tuff which had been thrown up from the earth's interior began to be worn down by atmospheric denudation, and the softer parts were removed, exposing the harder central stumps of the extinct volcanoes. Of these, Arthur's Seat, a typical instance originating in the calciferous age, remained dormant, according to Sir A. Geikie, all through the remainder of the Carboniferous period. In early Permian times it broke out again, but from that period till now has remained inactive, though it would hardly surprise a geologist to learn any day that Arthur's Seat was once more in an active state of eruption.

There is no subsequent record of volcanic action in Scotland until we come down to Miocene times, and this represents an immense interval of time, for between the Permian and Miocene formations lie the whole of the Mesozoic strata, together with the Eocene beds. It may be accepted as certain, however, that during the protracted period in which the New Red Sandstone, the Jurassic Series, the Chalk, and the Eocene strata were in course of formation no active volcanoes existed in Scotland. In the meantime all the species of plants and animals had changed; the old forms had become extinct, and had been replaced by entirely new races. But the volcanic forces, though so long dormant, had not permanently ceased; in the Miocene age a fresh outburst on a grander scale than ever took place. This

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time the greatest masses of lava were poured out on the western shores of Scotland. The basalts of the Giant's Causeway, Staffa, Skye, and the inner Hebrides are of Miocene age, these hardened lava floods attaining in Mull a thickness of over 3000 feet. Nor was the disturbance confined exclusively to the west, for all over Scotland there occur numerous trap dykes, generally running east and west. These have originally filled vertical fissures into which the melted lava was forced from below, passing up through the various horizontal beds. This lava solidified as it cooled, and long afterwards, in cases where the softer sedimentary strata, through which it rose, had been removed by atmospheric denudation, remained in the well-known form of a trap dyke. Such dykes of Miocene lava breaking through the sedimentary strata occur in all parts of the Fife coal-fields. A good example may be seen close to the shore, not far from St. David's.

The great belt of igneous rock which traverses the centre of Scotland from east to west, though continuous on the map, includes traps of various ages. The main masses west of Stirling, forming the Fintry, Campsie, and Kilpatrick ranges, and the traps of the Renfrewshire hills, belong to calciferous times; while the Ochils and the interbedded traps covering the northern zone of Fife, belong, on the other hand, to the earlier age of the Old Red Sandstone. From the circumstance that volcanic products are found interstratified with sedimentary rocks, we infer that the volcanic eruptions which threw up the former were contemporaneous with the deposition of the strata among which these volcanic products occur. These interbedded traps are well exposed in Glen Farg, through which runs the new railway route to Perth; they are also well seen near Newburgh station on the line to Ladybank.

Nearly all the hills of Fife are of trap, at least in their upper portions. This is apparent even from a distance, for the long level or slightly sloping lines and step-like terraced sides and ends outlined against the sky cannot be mistaken. But while the larger sheets are contemporaneous and interbedded, the smaller masses of later date are generally intrusive and break through, violently disrupting the subjacent rocks, which, from the effects of heat, are altered at the points where they come in contact with the trap. The older lavas differ in chemical composition from

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the more recent; the former being acid and containing excess of silica, while the latter are basic. They differ also in their mode of weathering—Abbey Craig, Stirling Castle, and Craigforth furnishing examples of concentric greenstone. Of similar character is the intrusive dolerite at North Queensferry, which weathers into rounded masses, often forming almost perfect spheres. This rock is extensively quarried for causeway and kerb stones. Good examples of jointing and very marked lines of ex-filtration may be seen in some of the quarries. Cavities are occasionally found filled with crystals of calc spar, or sometimes with bituminous matter having a naphtha-like smell, derived doubtless from the beds of shale through which, in a fluid condition, the rock was ejected. The island of Inch Garvie, on which rests the central cantilever of the Forth Bridge, is a narrow ridge of the same dolerite, rising abruptly from the bed of the Forth, which at this point is of great depth. A mile or so westwards, opposite the anchorage of St. Margaret's Hope, the dolerite gives place to dark-coloured basalt having the characteristic conchoidal fracture. On the beach at Rosyth Castle the basalt may be seen, its surface showing innumerable lines of cross fracture.

As has been pointed out by Sir A. Geikie, the traps of Carboniferous age in Fife and the Lothians occur as small isolated masses, while those of corresponding age in the western counties form extensive beds. Such isolated bosses and necks are very numerous along the shore, particularly in the east of Fife. On the beach between Elie and St. Monance may be seen several instructive examples of volcanic necks or vents, filled with basalt, or in some cases with agglomerate. The space occupied by volcanic rocks in the middle and southern zones is, however, small relatively to the total area, but the northern belt, with the exception of a narrow fringe of Old Red Sandstone strata on the south-side of the Tay, is entirely taken up by the interbedded traps which, as we have seen, were poured out by volcanoes at the beginning of the Old Red Sandstone period.

II.—The middle zone is formed of rocks belonging to the upper series of the Old Red Sandstone, and, in the valley of the Eden, these beds are exposed at a number of places. Not far from Dairsie station there is a fine section of cliff composed of massive yellow sandstones. The road passes between the river and the

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cliffs, which are about 60 or 70 feet high, while Dura Den, a beautiful spot and classic ground to geologists, is close by. These yellow sandstones have yielded numerous specimens of fossil fish, *Holoptychius*, *Glyptolepis*, *Pterichthys*, &c., and form the subject of a monograph by the late Rev. Dr. Anderson of Newburgh. The seam from which the fish were obtained lies along the bed of the stream. On the slabs preserved in the Edinburgh Industrial, in the Hunterian of Glasgow, and other museums, the fish occur in such numbers as to indicate that they perished suddenly. Exactly similar fossils have been obtained from the Heads of Ayr. During a recent visit to Dura Den the writer did not succeed in finding any ichthyolites but had the consolation of learning from a native that there were "plenty o' fine trout in the burn."

On the adjoining heights, from which one obtains a magnificent view of the Howe of Fife, are extensive freestone quarries where plant remains occur in great abundance. The thin uppermost seam is a veritable exhibition in black and white, but unfortunately the impressions soon fade when exposed to the action of the air. Casts of *Lepidodendron*, *Lepidostrobus*, *Calamites*, and others, possibly *Cordaites*, or perhaps the leaf stalk of a fern, are to be found in these quarries. *Stigmaria*, with the rootlets attached, is very frequent; these rootlets leave smooth groves in the fine-grained sandstone which might easily be mistaken for worm-tracks.

The yellow sandstones of Dura Den correspond with the Elgin beds from which the remains of fish belonging to the same genera have been obtained. The occurrence of reptilian remains in the newer Elgin beds is, however, indicative of Triassic age, and there is reason to suspect that these latter lie unconformably upon the Old Red Sandstone group below. Fish remains are also not uncommon in the lower division of the Old Red series to which the flagstones of Forfarshire and Caithness belong; and from the Carmyle quarries the remarkable crustacean *Pterygotus* is obtained, of which a magnificent specimen is preserved in Arbroath museum. The Old Red strata seem to have been deposited in a great inland lake, or possibly series of lakes, formed by the gradual shallowing of the Silurian seas.

III.—All the four main divisions of the Carboniferous system

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are represented in the southern zone of Fife. If a line be drawn from St. Andrews due south to Elie, all the triangular area to the east of this, as far as Fife Ness, consists of rocks of the calciferous sandstone group, with the exception of a small tract at St. Monance and Pittenweem. This small area is occupied by a part of the Carboniferous limestone series let down among the calciferous beds. In it there occur a number of coal seams, but of so poor a quality that they have been abandoned. Passing westwards along the coast, from Elie to Largo, we are on the mountain limestone series; from Largo to Pathhead we cross the Dysart coal basin, belonging to the upper coal measures. At Pathhead a narrow band of millstone grit is passed, and at Kirkcaldy we are again on the Carboniferous limestone. At Kinghorn and Burntisland there occur great masses of porphyrite with interstratified tuff, and between this and North Queensferry we return to the calciferous series. At the latter place, a great mass of intrusive dolerite has burst up through the calciferous shales and sandstones. The overflow has formed the massive beds of whinstone, 150 to 180 feet thick, which surround Inverkeithing Bay, and also the Ferry Hills which jut out into the Forth, contracting its channel by a half. On the outer edge of this mass of dolerite the northern piers of the Forth Bridge are built. When first seen by the writer the beach at this point vividly recalled a part of the shore at Catania on the coast of Sicily, where a lava stream from Mount Etna has entered the sea, the scenery of Fife generally, as viewed from the Forth, being Sicilian in character. West of the Forth Bridge the limestone group reappears and continues on to Culross; to the west of which, near Dunimarle, we get the Castlecary limestone and the millstone grit. Beyond Blair Castle the slaty-band ironstone comes in, and the Kincardine and Alloa coals, which belong to the upper or true coal measures.

We thus see that along the south coast section there are two principal areas of geological elevation, viz., in the extreme east of the county and on the portion between Burntisland and the Forth Bridge; on these areas the low-lying Calciferous series is thrown up to the surface. The general dip of the strata agrees with these main undulations, though there are frequent lesser foldings, and in many places, the strata are faulted and disrupted. Inland, the main faults run east and west; in the Dunfermline

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district there are four principal faults, ranging from 10 to 100 fathoms, by which the strata are thrown up towards the north. In general, the strata dip to the north, and as a result of the step-like faulting we meet, in passing northward, the same seams cropping out again and again.

(1.)—The calciferous series consists largely of flaggy sandstones, varying in colour from white to purple, and usually bearing ripple marks, with occasionally, the impressions of raindrops. These sandstones are well seen on the shelving shores at St. Andrews, Aberdour, and Rosyth. The shales, which attain a thickness of more than 100 feet, correspond with the oil shales so largely developed across the Forth in Linlithgowshire. From the shale oil is extracted at Binnend Works near Burntisland. This shale crops out again at North Queensferry, where it is traversed by a seam of clay-band ironstone.

A cliff near Rosyth Castle, consisting of thin beds of shale and compact earthy limestones, strongly recalls the Ballagan beds of the Campsie district, which also belong to the horizon of the calciferous or cement-stone series. Thin limestones occur here and there; of these the most interesting is the Newbigging seam, between Burntisland and Aberdour. This limestone is the equivalent of the Burdiehouse seam, and consists entirely of entomostracan remains. It is clearly a fresh-water deposit, and, from the appearance presented by the myriads of little *Cypris* cases of which it is made up, gets the name of seed-cake limestone. At various points between Kinghorn and St. David's occur masses of a peculiar volcanic breccia containing plant remains. This rock has evidently been formed out of pieces wrenched from different strata as the result of numerous explosions, for it consists of angular fragments of sandstone, *cypris* limestone, shale, and coal, cemented into a kind of concrete, sometimes hard enough to be used for building purposes. It may be seen in the immediate vicinity of the new pier at Aberdour. From it have been obtained many specimens of petrified wood in which the minute structure is admirably preserved. Fossil stems (*Lepidophloios*, &c.) from the porphyrite tuff of Burntisland have been made the subject of several interesting papers by Professor Williamson of Manchester.

On the whole, organic remains are scanty in the calciferous series, though scales of ganoid fish, and those doubtful structures

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known as conodonts, supposed to be the jaws of annelids, are found in some parts of the shale. The general character of the group points undoubtedly to a fresh-water origin; like the rocks of the Old Red Sandstone, the calciferous series must have been deposited either in an inland lake or in the estuary of some mighty river. The thickness of the series has been estimated at 2000 feet.

(2.)—The Carboniferous limestone series covers a larger proportion of Fife than any of the previously mentioned groups. It consists mainly of sandstones, coals, shales, and limestones, the limestone which forms its base being quarried in many places. There are large works at Charleston from which great quantities of lime are annually shipped to various markets. The rock is here over 50 feet thick; it contains 92 per cent. of calcic carbonate, and abounds in fossils, corals—*Cyathophyllum*, *Lithostrotion*, and *Zaphrentis* being among the number—and various species of *Productus* and *Crinoidea*. From the Calais Muir quarry, north of Inverkeithing, some species of *Orthoceras*, and heads of the crinoid *Poteriocrinus* have been obtained. In Roscobie quarries, north of Dunfermline, fossils representing a marine fauna of the most varied description abound, and of these a goodly collection is to be seen in the Smith Institute at Stirling. Very fine septaria, with pyrites containing traces of copper, are abundant in the marly shale at Calais Muir, and lead ore has been obtained in small quantity near Inverkeithing.

The Dunfermline coal-field, which extends from the Cullalo Hills on the east to the Saline Hills on the west, forms part of the mountain limestone series, and is thus equivalent to the Possil and Maryhill coals of the Glasgow area. It has been worked for over 600 years. In 1291, a charter was granted to the Abbot of Dunfermline by the proprietor of Pittencrieff, conferring the privilege of working a coal pit on that estate. About the middle of the fifteenth century an Italian, Æneas Sylvius, who afterwards became Pope Pius the Second, relates that when visiting Scotland he saw the poor people, who in rags begged at the churches, receiving for alms pieces of stone with which they went away contented, adding that they burn them instead of wood, of which their country is destitute. Boetius, referring to Scotland in an account written early in the sixteenth century, states that

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there "black stones are dug out of the ground which are very "good for firing, and such is their intolerable heat that they melt "iron and are therefore very profitable for smiths and other "artificers in metals."—(Chalmers' "History of Dunfermline," vol. i. p. 20).

The principal seams are known as the Dunfermline Splint or 4-foot, the 5-foot, and the 8-foot seams. In the Wallsend basin a 7-foot seam comes in above these, while the Little Splint, No. 3, the Ironstone, and Parrot form a still higher group, occurring in various pits. At the Elgin Colliery, a shaft of 105 fathoms passes through nineteen workable seams of coal, making an aggregate of 50 feet. This section shows 111 seams of alternating shale, sandstone, and coal, including altogether twenty-seven coal seams with a total thickness of 57 feet. Eastward, at Lochgelly pits, there are found in descending order, a 14-feet coal, the Lochgelly Splint and Parrot, the Mynheer, and the Splint, while at Donibristle we have the same series, with the limestone and calciferous rocks, cropping out on the flanks of the Cullalo Hills. From the last-named colliery have been obtained specimens of coal which were found by the late Professor Balfour to consist entirely of the spores of plants belonging to *Lycopodiaceæ*. Teeth of *Megalichthys* have occasionally been found in the Elgin and Halbeath pits. Seams of blackband ironstone occur in Townhill, Cowdenbeath, and several other pits, and near Oakley, to the west of Dunfermline, there were formerly extensive iron-works, but the furnaces have not been in operation for over twenty years. The Kirkcaldy series, also belonging to the Carboniferous limestone period, includes—in descending order—the millstone grit, thin coals, limestone, coal, Rough coal, Splint, the Duddie Davie, Black, Parrot, Upper Smithy, and Lower Smithy coals. On the St. Monance and Pittenweem area there are seventeen thin coal seams and five limestones, the latter with an aggregate thickness of 37 feet. In the extreme west of the county at Torryburn and Preston Island there is the following series:—Blackband, Lowrie Graham's, 6-foot, 9-foot, 5-foot, and 2½-foot seams. Preston Island, with its ruined buildings, forms a picturesque landmark in this part of the Forth. The seams just mentioned are inclined at a very steep angle, recalling the edge coals of Portobello. There is an old shaft on the shore near

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Torryburn which must formerly have communicated with the one on the island, for there is a well known story connected with it. King James VI. of Scotland was taken down on one occasion by his courtiers and when brought up to the daylight through the shaft on the island, seeing the water all around him, his suspicious nature gave vent to itself in the exclamation, "Treason! Treason!"

A little further west, in the flagstaff park at Low Valleyfield, we come on the outcrop of the Cowglen or "Index" limestone. West of this again, and still higher up in the series, are the outcrops of the Janet Peat coal and limestone. The latter is identified in the Survey with the calmy, Arden, or Hurlet seam. The strata at this point have been thrown into folds, and the dip changes rapidly; a trough is formed, and the Janet Peat limestone, which crops out just behind Culross Townhouse, is again encountered at Blair burn, further west. This seam occupies the same horizon as the Robroystone limestone which crops out in George Square, Glasgow. Beyond Dunimarle we get the Castlecary limestone and the millstone grit, west of which lies the Clackmannan and Alloa coal basin, where occur the Upper 5-foot, the 9-foot, the Cherry, and the Splint coals, all belonging to the true coal measures.

On comparing the Carboniferous limestone series of Dunfermline with the corresponding strata of the Edinburgh or Glasgow districts, one is struck with the paucity of limestone in the former. No limestones have yet been found in the upper coal measures of the Glasgow district, so in this respect the Dunfermline basin, though belonging to the lower, rather resembles the higher series. It would appear that during the latter part of the mountain limestone era the deeper water lay to the westward, and that the Dunfermline area was occupied by a shallow lake or estuary, on which the accumulation of river sediments took place, the conditions being unfavourable to the formation of calcareous strata.

(3) The millstone grit covers but a small part of Fife. West of Dysart is a narrow strip running north to a point west from Thornton, and we do not meet with it again till near Kincardine, where it occupies Culross Moor and Tulliallan forest. Its strata consist of the characteristic coarse-grained sandstones and fine quartz conglomerates.

(4) The upper or true coal measures in the Dysart basin include eighteen seams, known as Wemyss Castle; Wall; Barn Craig, 5′ 6″;

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Upper Coxtool, 3′ 6″; Lower Coxtool, 3′; Den, 2′ 2″; Chemiss, 9′; Bush, 3′ 6″; Parrot, 2′ 3″; Wood Coal; Earl's Parrot, 2′; Bowhouse, 6′ 6″; Brankston, 4′; Boreland; Shandwell; Dysart Main, 21′; Clayband ironstone, 2′; and the 7-foot coal. Inclusive of the lower seams of the limestone series, we have a theoretical aggregate thickness of 120 feet of coal on this area. When we compare the Dysart series with that of Dalkeith, the general correspondence points to both areas having once formed part of the same basin. The Dysart Main seam of 21 feet, for example, may very well correspond with the 15 feet seam at Portobello, while a 7 feet seam forms the base of both series. As a whole, however, the beds must have thinned out towards the north, for a section in one part of the Edinburgh field passing down through 3000 feet of strata reveals fifty-eight coal seams, with a total thickness of something like 150 feet. The equivalents of the Dysart series are to be found in the district east of Glasgow—*i.e.*, at Rutherglen, Shettleston, Bothwell, Coatbridge, and Airdrie, all situated on the upper coal measures; the Upper Soft, Ell, Main, Humph, Splint, and Virgin coals of the Bothwell pits, and the Blackband, Musselband, Virtuewell, and Drumgray seams of the Airdrie pits being their representatives in the western coal-field.

The number of these Dysart and Dalkeith coal seams, as well as their total thickness, may well induce us to pause and reflect on their geological significance. A coal seam approximately represents an old land surface, being composed for the most part of the remains of terrestrial plants, which cannot grow without air and light. When, then, a coal seam is discovered at a depth of 3000 feet, this affords conclusive evidence that the land has been depressed to something like this extent. But fifty or more coal seams may be superposed one above another, with beds between them of sandstone and shale which could only have accumulated under water. All this could, of course, be explained on the theory of alternate elevation and depression of the land level. Such oft-repeated alternations are not indeed impossible, but it is much simpler to suppose that it was brought about by the continuous sinking of the coal area. The formation of a coal basin may be accounted for in some such way as this—first, we may suppose that over a certain extent of land surface a quantity of vegetable matter sufficient to form a seam of coal had accumulated;

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next, that by depression this area became submerged, and was buried under sand and mud brought down by river action from the neighbouring land; that this sediment continued to be deposited until the depressed area was completely silted up and the river confined to a narrow channel. In this way the level would be restored, and, vegetation again taking possession of the ground, material for the second coal seam would in course of time be formed. This process repeated time after time would ultimately, as the subsidence continued, give rise to a series of strata like those of which the Carboniferous system is built up. But the lapse of time, which a system many thousand feet in thickness, and formed in this way, must represent, transcends the powers of imagination to grasp.

The upper beds of the Carboniferous system consist of thick red sandstones, which are well developed at East Wemyss. These rocks are here, as the name of the place indicates, pierced by numerous caves hollowed out by the action of the sea. These are not so extensive as those of the Arbroath coast, nor does the sea reach them now, for they form part of a Raised-beach. These red sandstones are perhaps the youngest rocks in Fifeshire, for mesozoic strata are entirely absent. If they ever existed, they have long since been removed by denudation.

It only remains to mention the Boulder-clay, which attains in places a thickness of 90 feet, and the Post-tertiary beds with glacial shells, exposed at low water on various parts of the coast. During the Ice age the physical conditions all over Scotland were so uniform that these deposits offer no features of special interest.

Sub-aërial accumulations are represented by the sand dunes along the southern shores of the Tay and by the golf-links of Leven, Largo, and St. Andrews. There is a good example of a Raised-beach above the pier at Aberdour, where marine shells of existing species occur in beds at a level quite 40 feet above the present high-water mark.

In the west of Fife the old coast-line can be traced in some places fully a mile inland from the present beach, and here and there a second or intermediate coast-line can be made out. At Kincardine 360 acres have been reclaimed from the river by means of a sea-wall constructed after the Dutch fashion. Between this town and Stirling the numerous windings of the Forth and the

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alluvial flats on either bank furnish convincing proofs of the power of a river to restore a depressed level. Many years ago the skeleton of a whale 70 feet in length was discovered north of Stirling at Airthrey, near the northern limit of the alluvium, at a level 22 feet above the highest spring tides of the present day; and the remains of seals have been dug out of the brick-clays of Strath Eden. The evidences of recent depression are not so obvious in Fife as those of elevation, but submerged forests are stated to occur on the coast near Largo and in the Tay. There are a number of dried-up lakes throughout Fife, one of which is situated to the north of Aberdour. In constructing the railway between the Forth Bridge and Inverkeithing, after tunnelling the whinstone, a small ravine had to be crossed. The embankment thrown over this space kept sinking for months, the adjoining high road was pressed up 25 feet above its former level, and a neighbouring field was converted into a series of hillocks by the displacement of the subsoil, which apparently consisted of fine laminated clay.

On the shore at Port Laing, which is in the immediate vicinity, some years ago two ancient canoes were discovered, and on the hillside near North Cliff a Roman road can still be traced. In the museum of the Society of Antiquaries, Edinburgh, may be seen a pair of Celtic urns found at Craig Dhu, North Queensferry, in 1859; and quite recently a series of similar urns were unearthed at Pitreavie, south from Dunfermline. Rough and polished stone hatchets have occasionally been picked up in the same neighbourhood.

Marvellous is the story furnished by these stony records of the past, marvellous what they tell, more marvellous what they leave untold, of long protracted ages and innumerable forms of life that have come and gone, leaving behind them no memorial of their existence. Neither the pterodactyl nor the deinosaur have left their footprints on the shores of Fife, for this reason, that of all the natural phenomena which occur in any locality, while some are duly recorded in earth's rock-leaved annals, others unchronicled, as in the case of that long geological drama of mesozoic times, are destined to dissolve,

> "And, like this unsubstantial pageant faded,
> Leave not a wrack behind."

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No. XXXV.—Notes on a Visit to the Culbin Sands, Morayshire. By James Barclay Murdoch, *Hon. Sec.* With a Map. [Plate, No. XVI.]

[Read 16th January, 1891.]

(Abridged.)

On two occasions in the months of July and August, 1890, I carried out a long-deferred intention of visiting the northern counties of Banff and Elgin (or Moray). Amongst other places I saw Portsoy, Elgin, Lossiemouth, Grantown and Speyside, and Forres, with the Valley of the Findhorn. Whilst at the last-mentioned town I spent some time amongst the sandhills of Culbin, which skirt the coast-line between Findhorn and Nairn. Days might have been spent profitably and agreeably at Portsoy, with its serpentine and graphic granite, or at Elgin, with its sandstones and reptilian remains of much disputed age and succession; but the bare and arid wastes of "Coobin" had for me a surpassing interest, both geological and archæological, and I purpose, therefore, on the present occasion, to confine my remarks to some of the salient features of that district.

Unlike our own Ayrshire sandhills, so well described by Mr. John Smith (*Transactions*, vol. vi., part 2, p. 185), these northern sand accumulations remain much as they have been for generations, for there is no extent of population or industrial occupation near them, and, with the exception of some small amount of tree-planting on their inland border, no attempt has yet been made to curb their shifting and erratic formation. Perhaps nowhere better in Scotland can the observer have an opportunity of noting the unfettered action of wind-blown sand than in this Morayshire desert.

Great geological interest attaches to such sand-action as bearing upon the origin and formation of sandstones of various ages. Green, in his "Geology," 1880, p. 149, says, "Another very common form of terrestrial accumulations is that of Blown Sand. . . . These often show, when cut into, rude bedding, and the action of the wind produces in them structures exactly analogous to the current-bedding and ripple-drift of subaqueous sandstones. In some cases the sand is mixed with broken shells, and water percolating through the mass dissolves out the carbonate of lime and

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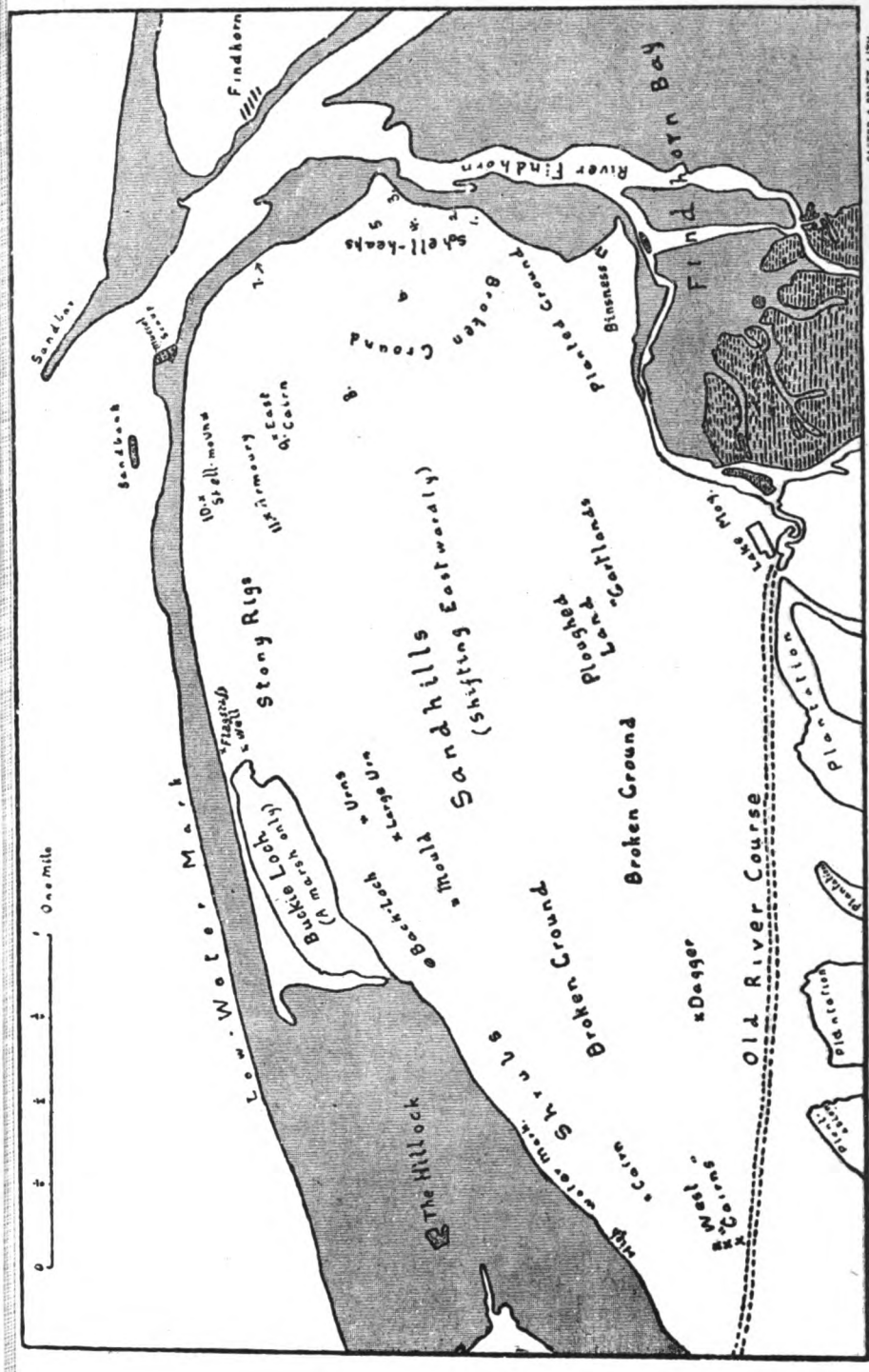

SKETCH MAP OF CULBIN SANDS, MORAYSHIRE.

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re-deposits it as a cement, so that a hard calcareous sandstone is produced. . . . It is therefore possible that some of the sandstones of the earth's crust may have been originally Blown Sand."

And Beete Jukes, in his "Students' Manual," 1862, p. 154, under the title "Aërial Rocks," after describing many instances of such deposits, quotes De la Bêche, that on the coast of Cornwall the sand, composed largely of fragments of shells and corals, sometimes becomes converted by carbonate of lime or oxide of iron into a hard stone.

The total area known as the Culbin Sands has been stated to be about 10 miles long by 3 broad, or an area, roughly speaking, of about 4000 acres. The largest consecutive stretch of the sandhills is, however, about 4 miles by 2, and its shifting covering varies from almost nothing to nearly 120 feet, a height reached by some of the larger hills. One of these, lately measured, had a base area of 440 yards by 220, its longest axis being east and west, like those of the other hills. Taking the above lesser area with its heights and hollows, a young engineering friend has calculated for me that the accumulation of sand upon it represents a weight of something like 50,000,000 tons.

The surface and position of all this vast body of silicious particles is changing from day to day and from hour to hour at a rate which of course varies greatly, being dependent on the force, direction, and velocity of the wind. It is said that in this district the wind blows from a westerly direction three days out of four, and in stormy dry weather a very short time suffices to materially alter the sandhills with their corresponding valleys. At the time the Ordnance Survey was made, the greatest elevation was found to be 99 feet, while at present it is considerably over 100 feet.

A noticeable feature in the formation of sandhills is the great difference between the gradients of their sloping sides, the leeward sides having at least double that of the windward ones. At Culbin, as already remarked, the western side is the windward one, the wind from that "airt" averaging more than double that from all other quarters.

To any one who has traversed the sand wastes of our western and northern coasts, the wind-formed ripple-marks are a very marked characteristic; they are quite as frequently formed in this

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way as by the action of water on a sandy shore. In certain sandstone strata such ripple-marks are as plain as if they had been formed to-day. And in some of their hollows may be traced layers of different coloured, perhaps lighter, material, just as we see in recent examples.

Certain darker coloured bands and layers of stratification, seen on the surfaces of some of the sand slopes at Culbin, seemed to form remarkable patterns, which brought vividly to one's mind the wavy band lines on "watered" silk. These I have seen also on some of the Irish sandhills, and from appearances on some of our sandstones they must have been similarly formed in geological times.

When the encroachment of the blown sand on the cultivated fields and pasture lands of Culbin first began is not known to history, but there are in existence various notices recording successive disasters which came with storm and flood. Buchanan, in his "History of Scotland," states that about A.D. 1000 there was an inroad of the sea which not only overflowed the fields and covered them with sand, but swept away many houses. Boethius, another historian, mentions that at the time of the formation of the Goodwin Sands (*i.e.*, about A.D. 1100) the sea desolated part of Moray and destroyed the fields with sand.

But not till about the year 1650 do we find wind-blown sand spoken of. Then it appears to have reached the grass lands lying inside and along the Raised-beach terraces which lined the coast. Year by year afterwards it overran these grassy reaches till, in 1676, it reached the grain fields. On 17th July, 1695, Alexander Kinnaird, the then proprietor of Culbin, petitioned Parliament to be exempt from cess tax, "because his estate, which, twenty years previously, was one of the most considerable in Moray, was nearly all covered with sand, and the mansion-house and orchard destroyed." Two years later he again applied for a personal protection from his creditors, on the ground that three-fourths of his estate were overrun with sand, and the remaining fourth part had already been sold for their benefit.

Culbin appears to have at one time carried a considerable population. There were a number of small farms, besides the Home farm, and many crofts occupied by fishermen, just such a state of matters as exists on many parts of the coast at the present

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day. There was a church on the ground, the site of which is still known as the Chapelhill. The local belief is that the estate, with its mansion house and many of the cottages were blotted out of existence by the sand blast on one awful night of storm. More probably, as previous statements shew, that was not the case, but that after a struggle for years against the advancing wave, one tempestuous night completed the half-finished destruction of houses and fields.

About the beginning of this century a tremendous gale which raged for several days shifted the sandhills to such an extent that buildings were exposed to view, including the old mansion. And it is said that so long as it re-appeared it formed a convenient quarry for the house-builders of the district, who treated it in the same ruthless manner that has worked woe to our old castles. A later storm again hid its remains from the spoiler, and it still remains buried in its sandy covering.

Previous to these days of misfortune the estate of Culbin, with the adjoining properties, formed part of the rich and fertile tract of country which was known as the granary or "girnel" of Moray, from the richness and earliness of its crops, a character which the existing arable lands still maintain. No doubt this long-continued fertility is due largely to the fact that the great alluvial tract which borders the sea for many miles, along the southern shore of the Moray Firth, is the long-accumulated result of combined river and sea action, and has had stored up in it all the constituents of plant life.

Seawards of the sandhill area, and along the shore of Findhorn bay, lie stretches of Raised-beaches which were formed previous to the last rise of the land; they are known in the district as "stony riggs," consisting largely of water-worn pebbles of various sizes. Again bordering on, and inland from, these are low terraces covered with dark sandy soil, and carrying on their surface many shell-mounds of all dimensions.

In the latest edition of Shaw's "History of Moray," 1882, the editor states that "the relics obtained from the old lands of Culbin belong to a period too close at hand to be of much interest to the antiquary." But this is a grave misstatement, for the portions of ground just described, alternately covered with, and bared of sand, have of late years yielded a rich harvest to the antiquarian, and

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the Edinburgh Museum of the Society of Antiquaries of Scotland has received from this locality many thousands of flint and stone implements, including arrowheads, knives, scrapers, axes, hammer stones, whorls, querns, &c., besides numberless articles of pottery, bone, bronze, and iron.

Such remains of the old inhabitants bear evidence, as well as that afforded by the shell-mounds, to the long-continued prehistoric occupation of the district. These enormous accumulations of shells, often called "kitchen middens," are largely composed of the shells of edible molluscs, such as the oyster, cockle, mussel, whelk, limpet, and periwinkle. The oyster is said to be now altogether or almost extinct in the Moray Firth, and if such is the case there must have been a great change from the old conditions under which it flourished. It thrives on muddy flats but is killed by sand, and the presence of its shells in abundance in the old shell-mounds, and its subsequent disappearance as a living animal, emphasize the evidence afforded by the sand invasion of the cultivated and pastoral lands.

And whence has come this influx of sand? There have doubtless been considerable alterations of shore-line along this part of the coast, even in comparatively recent times, and the sea has attacked and removed a large amount of previously existing shore deposits. Great waste by denudation of the upper strata of the surrounding districts must have been going on for ages, and the Moray Firth itself is a huge slice carved out of the Old Red Sandstone, which still lines both its northern and southern shores. The strong and rapid currents of the Spey, the Findhorn, the Ness, the Beauly, the Conon, and the waters which empty themselves into the Cromarty Firth, not to speak of the smaller streams, are constantly carrying down to the sea burdens of sand derived from the strata through which they pass. Some of these rivers, and notably the Findhorn, are prone to extraordinary and sudden floods, which, bringing down from the higher grounds quantities of debris, subject the rocky banks to enormous wear and tear.

As regards the Findhorn, its action as regards the sand is something like the following. Discharging itself into a land-locked arm of the sea, known as the Bay of Findhorn, which has an area of about 1000 acres, the sands it bears are first carried down to the open sea, then borne by the tides and currents westwards for a

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certain distance, till they are thrown up all along the southern coast of the Moray Firth towards Nairn. Then, coming under the influence of the prevailing westerly winds, the sand is blown into Culbin, which retains it for a longer or shorter period till it eventually finds its way to the western side of Findhorn Bay, and back into the river channels, through which it travels seawards, again to repeat its endless round.

But for this watery barrier, which it never crosses except in times of high storm, the travelling sand would have desolated much of the land lying to the east of Findhorn Bay. Indeed, we know that at least on one occasion the sand did manage to pass over, invading the fertile parishes of Kinloss, Duffus, and Alves, where its remains, in the shape of grass-covered mounds, are still to be seen, though much of the more slightly covered ground has been reclaimed by having the old soil trenched up above the sand.

It should be stated that the whole area of Findhorn Bay has now become filled with sand which is dry at low water, with the exception of the two river channels. That of the river Findhorn is now some miles eastward of its old course, a change probably gradually induced by the action of the flowing sand.

On the inland edges of the sandhills, plantations of Scotch firs have of late years been made, with the intention, which seems to have been fairly successful, of arresting the southern influx of the sand. Most of the trees I saw were thriving, though in some places more or less buried, and I heard that in one plantation the sand had quite overtopped them.

In some of the flat bottoms at the foot of the sandhills the old surface black soil was laid perfectly bare, with the rigs of the ancient cultivation distinctly visible. Numbers of water-worn pebbles and angular fragments of stone were lying scattered over it, and all of these, except a few of soft formation, shewed the most wonderful polish from the continual sand blast. Though the old soil seems to have been buried for at least 200 years, it still retains the dormant seeds of vegetation, and, when freed from sand for one year, begins to throw up a strong plant growth. In February, 1817, the late Sir Thomas Dick Lauder caused a couple of flower-pot saucers to be filled with a sample, and in the following May he found that a tender growth of no less than 46 plants of 4 species had sprung up in them. These he

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identified as Mouse Ear (*Cerastium arvense*), Scorpion Grass (*Myosotis scorpioides*), Purple Archangel (*Lamium purpureum*), and Corn Spurry (*Spergula arvensis*), all of them being plants which we know as "field weeds."

I have found that the best time to visit Culbin, or similar localities, is on a fine morning after rain, as then the surface of the sand is moist, and the usually moving grains of silica are quiescent. When there is a breeze, however light, unless the surface is damp, the untiring oncome of the sand soon becomes unpleasant, while in high wind it is decidedly disagreeable, if not dangerous.

One day I drove from Forres to Culbin, past Kingcorth, was such an ideal occasion—the bright blue sky and the gentle breeze had come after a wet night, and the sand surface was moist and firm, affording good footing everywhere. The slopes exposed to the sun were beginning to dry in patches. Soon we reached the top of one of the highest hills, and how splendid was the outlook! In the foreground sandhill after sandhill, hollow beyond hollow. Then the bright sparkle of the Moray Firth, with the receding coast line of Ross and Cromarty fading into the northern distance, and the Dunrobin cliffs with some of the more distant hills showing clear against the sky-line. Long we looked, and map in hand, puzzled out each point in this classic ground.

From this we descended into one of the intervening valleys, where all traces of the world were shut out, and except the sky above, sand, and sand alone, met the eye. Life, animal or vegetable, was entirely absent. Winding along through the branching hollows, we at last reached the southern edge of the sand drift, but it was easy to realize that in storm or darkness it would be almost impossible to find one's way.

Of the locality during such times I had no experience, but all accounts agree in saying that it would be foolhardy to try to cross Culbin on either occasion. The editor of Shaw's "Moray," 1882, already referred to, seems to have had an exciting time in an attempt to cross it during a storm, but his account is too long for quotation, and reference may therefore be made to the work itself.

It is only after stormy weather, when the sand has somewhat shifted, and before the relic-hunters are abroad, that prehistoric

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remains are likely to be met with, so I did not meet with any. I crammed my pockets with the polished pebbles, which glistened brightly in the sun, and at a miniature waterfall (of sand), which, from the influence of the breeze above, was falling over a steep bank, I filled my handkerchief with the flowing silicious grains which were of the finest and most uniform quality. As to the latter, I afterwards found I need not have taken any trouble, for, on my return to Forres, I discovered, that slight as the breeze had been, it had loaded every pocket, every fold of dress and umbrella, with so much fine sand, that I had unconsciously brought away with me nearly as much as the amount of my gathered sample.

[A fully illustrated "Report on the Archæological Examination of the Culbin Sands," by Mr. George F. Black, which was read before the Antiquarian Society of Scotland, on May 11, 1891, has been published in the Society's volume of Proceedings for 1890-91, and will well repay perusal. By the courtesy of the Council of that body I have been enabled to append to my paper a reduced copy of the Sketch Map drawn by Mr. Black to accompany his paper, and for the use of which I have to return my best thanks.—J. B. M., *Jan.* 1893].

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PROCEEDINGS FOR SESSION 1890-91.

(33RD SESSION.)

SOCIETY'S ROOMS, 207 BATH STREET, 9TH OCTOBER, 1890.

Mr. DUGALD BELL, *Vice-President*, in the Chair.

Mr. William Scott, 3 M'Aslin Street, Glasgow, was elected an Ordinary Member.

The CHAIRMAN welcomed the Members on their assembling to open a new Session, and hoped that all would contribute to make it a useful and interesting one.

Mr. D. C. GLEN, F.G.S., the Society's delegate to the recent meeting of the British Association at Leeds, gave an account of the more interesting geological papers and excursions there.

Mr. JAMES WHITE, *Hon. Librarian*, read a paper entitled "Notes on Lewis, with Chips of the Rocks." In it he summarised the writings of the various authors who had discussed the geology of the island, and then gave his own views regarding the stratigraphical position of the rocks, their glaciation, and the distribution of boulders.

At its close some remarks were made by Mr. William Jolly, F.G.S.; Mr. John Young, F.G.S.; and the Chairman (Mr. Bell).

SOCIETY'S ROOMS, 207 BATH STREET, 13TH NOVEMBER, 1890.

(ANNUAL GENERAL BUSINESS MEETING.)

Mr. JOSEPH SOMMERVILLE, *Vice-President*, in the Chair.

The HON. SECRETARY (Mr. Murdoch) read as follows:—Report of the Council for the year ending 30th September, 1890. [See page 434.] The *Hon. Treasurer* (Mr. John Wight, C.A.), submitted his financial statement for 1889-90. [For Abstract of Accounts, see page 442.] The *Hon. Librarian* (Mr. James White) read his report upon the business of the Library for the year ending 30th September, 1890.

After some remarks by Mr. Dugald Bell, Mr. R. J. Steele, and other members, the adoption of the reports was unanimously agreed to.

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The Rev. Mr. MACKINTOSH then proposed a hearty vote of thanks to the Honorary Secretaries (Mr. James B. Murdoch and Mr. Gavin M. Pratt), to the Honorary Librarian (Mr. James White), and to the Honorary Treasurer (Mr. John Wight, C.A.), for their work in the interests of the Society. The motion was seconded by Mr. John Young, F.G.S., and cordially agreed to.

The election of office-bearers was next proceeded with, and the undernoted members were declared to be duly elected to fill the vacancies in the Council for a term of three years:—President, Sir William Thomson, F.R.S.; Vice-President, Mr. William Jolly, F.G.S.; Members of Council, Messrs. Dugald Bell, James Clark, Robert Dunlop, John Renwick, and Dr. S. Sloan; Auditors, Messrs. David Pearson and James Steel; Hon. Secretary, Mr. James B. Murdoch, F.R.Ph.S.E.; Assistant Hon. Secretary, Mr. Gavin M. Pratt; Hon. Treasurer, Mr. John Wight, C.A.; Hon. Librarian, Mr. James White.

The following gentlemen were elected Ordinary Members:—Messrs. Alexander Birrell, 227 West George Street; Robert Brownlie, 8 Ardgowan Terrace, Sandyford; W. B. Hair, 226 West Regent Street; and William M'Ewan, 148 Bothwell Street.

Mr. JOHN HOWAT exhibited, with remarks, a number of fine specimens of Double Termination Quartz Crystals of great brilliancy from Little Falls, New York State, U.S.; also a series of Silurian Fossils from the same locality.

Mr. JOHN YOUNG, F.G.S., *V.P.*, exhibited specimens and sections of an ultra-basic crystalline rock of igneous origin, belonging to the Peridotite group, which were taken from the spoil-heap at the southern end of the new tunnel of the Glasgow Corporation Water-works, which passes through Mugdock Hill, Milngavie. He said that Peridotite seems to be eruptive amongst the older igneous rocks of the Mugdock district, and that it belongs to a class of rocks noted for their high specific gravity and for their bearing evidences of having been thrown up from deeper sources than those from which the associated igneous rocks were derived. In the present specimens the olivine crystals are seen to be moderately large and fairly numerous, appearing to have suffered little alteration in their colour and composition. They are imbedded in a matrix of basic felspar, with magnetite and titanic iron in grains. Specimens of a similar rock from Langbank, on the Clyde, show a great alteration of the olivine crystals, their colour having been changed from its normal olive green into a deep red, which was due to the oxidisation of the iron present in their composition. Such ultra-basic rocks as the Peridotites are rare in most parts of the world, but seem to have been erupted at several points in the trappean hills round Glasgow. They are interesting to petrologists from the fact that their mineral composition approaches closely to that of some of the meteoric bodies which have reached our earth from space.

Remarks on the subject were also made by Messrs. Dugald Bell, David Ross, LL.D., and the Chairman.

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SOCIETY'S ROOMS, 207 BATH STREET, 11TH DECEMBER, 1890.

Mr. JOHN YOUNG, F.G.S., *Vice-President*, in the Chair.

Mr. Ronald M. Johnstone, C.E., 75 West Nile Street, and Mr. James Reid, 26 Westmuir, Parkhead, were elected Ordinary Members.

The CHAIRMAN called attention to the honour which had been conferred upon the President of the Society, Sir William Thomson, in his recent election to the Presidentship of the Royal Society, a distinction which had not, he believed, been conferred previously upon any member of that learned body who was not resident in London. Mr. D. Bell proposed and Mr. D. C. Glen, F.G.S., seconded a motion that the Hon. Secretary be instructed to congratulate the President, on behalf of the members, on his appointment to the highest scientific post in Great Britain.

Mr. ROBERT DUNLOP exhibited, from the cabinet of Mr. Jack, Airdrie, a specimen of a fossil spider, *Palæophalangium Scoticum*, from the Carboniferous shale overlying the Kiltongue coal near Baillieston; also several beautiful drawings of this new form on an enlarged scale, by Mr. B. M. Peach, of H.M. Geological Survey, who had undertaken to describe it for the Society's *Transactions*. Mr. Dunlop said that it used to be commonly believed that Carboniferous vegetation was devoid of animal life, but through the labours of Mr. James Bennie, of the Geological Survey (a member of this Society), and other workers, such an idea was now quite exploded. If collectors of ferns and other Carboniferous plants would keep their eyes open when searching the shale-heaps many new forms wonld doubtless yet be discovered.

The CHAIRMAN (Mr. Young) exhibited under the Society's microscope sections of Peridotite, an ultra-basic igneous rock, which he had prepared from a small chip received from Mr. John Smith, Kilwinning, stating that he exhibited them in illustration of the changes which had taken place in their constituent olivine through weathering or whilst lying in the earth's crust. At last meeting of the Society he had exhibited specimens of Peridotite from the Mugdock Tunnel, near Milngavie, in which the olivine crystals were little altered from their normal olive-green colour. In the specimen from Kilwinning the alteration of the olivine by oxidation of the iron is seen to have been completed in all the smaller crystals, while in the larger ones the change has not advanced far beyond the outer margins, the colour showing an outer border varying from red to orange-red and yellow. These surround the less altered portion of the olivine, which is now of a pale bluish-green colour, and in which is developed a new crystallisation consisting of a finely fibrous stellate structure, like that seen in delessite. Zonal bands of silica or an allied mineral surround many of the crystals, and the rock under its altered condition forms a most beautiful and interesting object for microscopic investigation.

Mr. D. C. GLEN, F.G.S., exhibited cores of the various Carboniferous rocks which had been passed through during the progress of a bore at present being put down at Wellpark Brewery.

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Mr. JAMES WHITE showed an *Echinus* spine, *Cidaris grandiferus*, of a curious fruit-like form, found in Cretaceous rock in the Holy Land.

Mr. JAMES S. M'LENNAN read a paper entitled "The Geology of Kyle" [see page 264], which was illustrated by the Geological Survey maps of the district. At its close an animated discussion was taken part in by several members.

SOCIETY'S ROOMS, 207 BATH STREET, 16TH JANUARY, 1891.

Mr. WILLIAM JOLLY, F.G.S., *Vice-President*, in the Chair.

Mr. Arthur Pollock, Manager, Dillichip Works, Bonhill, was elected an Ordinary Member.

Mr. JOSEPH SOMMERVILLE called attention to the death of a distinguished Honorary Associate of the Society, Mr. James Croll, LL.D., and paid a feeling tribute to the memory of the deceased gentleman. The Chairman said the members of the Society owed it as a duty to themselves, and to the memory of the deceased member, to adopt such a motion as that shadowed forth by Mr. Sommerville. Dr. Croll had done much special and original work which was not yet fully recognised and acknowledged as it ought to be by the world of science. Mr. John Young, F.G.S., corroborated the Chairman's remarks and spoke of Dr. Croll's early association with Glasgow, and his first connection with the Society. The Chairman then moved, and Mr. Dugald Bell seconded, a motion that an expression of deep regret at the decease of Dr. Croll should be recorded in the Society's minutes, from which an extract should be forwarded to Mrs. Croll.

Mr. JOHN HOWAT exhibited specimens of Cornish Granite and Kaolin (China clay) resulting from its decomposition, the latter product being largely imported to Glasgow and elsewhere for the manufacture of china-ware.

Mr. JAMES B. MURDOCH, F.R.Ph.S.E., *Hon. Secretary*, read a paper entitled "Notes on a Visit to the Culbin Sands, Morayshire" [see page 406], which was illustrated by a map of the district and by various specimens. At its close, a discussion was taken part in by the Chairman (Mr. Jolly), Mr. John Young, F.G.S., Mr. Joseph Sommerville, Mr. Dugald Bell, Dr. Sloan, and other members.

SOCIETY'S ROOMS, 257 BATH STREET, 12TH FEBRUARY, 1891.

Mr. JOHN YOUNG, F.G.S., *Vice-President*, in the Chair.

The death of Mr. Robert Mason, F.L.S., long a member and office-bearer of the Society, was referred to by the Chairman, and remarks were also made by several other members. It was unanimously agreed that an expression of regret at Mr. Mason's death should be entered in the minutes.

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Mr. David Stirling, coalmaster, Kilsyth, was elected an Ordinary Member.

Mr. DUGALD BELL exhibited specimens of Labradorite from Newfoundland. It is a triclinic felspar, and is especially a constituent of the augitic rocks, such as dolerite, basalt, hypersthenite, &c.

Mr. JOHN RENWICK exhibited a specimen of Crocidolite from Orange River, South Africa.

Mr. ROBERT DUNLOP exhibited specimens of Barium Sulphide and of Lead Crystals from Leadhills, South Lanarkshire, and made some remarks upon their occurrence and composition.

The CHAIRMAN (Mr. Young) read a paper "Notes on the Group of Carboniferous Ostracoda found in the strata of Western Scotland, with a Revised List of Genera and Species" [see page 301], which was illustrated by a large number of mounted specimens, shewn under the Society's microscope.

The HON. SECRETARY (Mr. Murdoch) read, on behalf of Mr. John Smith, Kilwinning, a paper upon "Peculiar U-shaped Tubes in Sandstone, near Crawfurdland Castle, and in Gowkha Quarry, near Kilwinning." [See page 289].

SOCIETY'S ROOMS, 207 BATH STREET, 12TH MARCH, 1891.

Mr. JOSEPH SOMMERVILLE, *Vice-President*, in the Chair.

Mr. JOHN YOUNG, F.G.S., *V.P.*, exhibited (1) a specimen of Carboniferous Sandstone, containing one of the curious U-shaped burrows described by Mr. John Smith in his paper read at the previous meeting, and supposed to have been the home of a sand-boring annelid or crustacean [see page 289]. Mr. Young shewed (2) a large slab of Carboniferous Shale from one of the roof coals of a pit at Mount Vernon, which contained two beautifully-preserved impressions of the fronds of a Fossil Fern, *Alethopteris lonchitica*, a characteristic species of the Scottish Upper Coal Measures. Mr. Young exhibited (3) a specimen of Anthracitic Coal from the recent excavations at the base of the Necropolis hill for the Wellpark Brewery Co. This coal has been rendered columnar through partial fusion from contact with heated igneous rock (dolerite). The columns are polygonal, and about half-an-inch in diameter. All the above specimens had been presented to the Hunterian Museum, the first by Mr. John Smith, the others by Mr. Thomas Naismith.

Mr. JAMES B. MURDOCH, *Hon. Secretary*, exhibited two specimens of Fused Rock, one shewing columnar structure, from the Vitrified Fort on one of the Burnt Islands, Kyles of Bute, and made some remarks upon the origin and structure of these interesting prehistoric remains. He stated that Hugh Miller, in his "Rambles of a Geologist," appended to his delightful "Cruise of the Betsy," had well summarized the theories formed by previous writers:—(1) That of Pennant, who supposed Vitrified Forts to be volcanic in their origin, and simply the outer rims of extinct volcanoes! (2) That of Williams, one of our earlier British geologists, who held that

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they were designedly vitrified in order to cement into solid masses their loosely formed walls. (3) That of Lord Woodhouselee, the historian, who thought the stone walls had been merely the foundations of higher wooden structures, and that their vitrification had accidentally happened when the upper buildings were destroyed by fire. (4) The view of Sir George Mackenzie, who believed that the fusing of the stones proceeded from beacon fires, kindled to warn the neighbouring inhabitants of the presence of a foe.

Hugh Miller himself inclined to the second theory, that the walls were purposely vitrified, though afterwards they may, from their situation in many instances, have been used as the sites of beacon fires. Mr. Murdoch said that so far as he had seen such forts there seemed to be little room for doubt that the fusing of the stones composing the walls was designed to weld the roughly-built materials into a solid mass, both for defensive purposes and to resist the action of the weather. The vitrification is much too regular to be the result of accident. It was probably induced by the action of an alkali—in inland situations, from wood ashes—in such a locality as the one from which the present specimens came, from sea-weed. Had the walls at the Burnt Islands been untouched Mr. Murdoch would not, he said, have been the one to disturb them, but they were, he was sorry to say, not much more now than upturned confused masses, with many detached portions lying in all directions. Whether treasure-seekers, rabbit-hunters, or mere mischief-makers, had been guilty of this vandalism there is no record to shew. There were still many existent examples of these interesting structures to be met with in the Clyde district and elsewhere, but it was not his purpose at the present time to do more than allude to them in connection with the theory of vitrification.

Mr. Murdoch then read, on behalf of Mr. John Smith, Kilwinning, a paper on "The Ardrossan Shell Mound, with an account of its Excavation" [see page 355]. This mound was thoroughly investigated by the author some years ago where it lay, at the Rock Shelter, close to the Ardrossan station of the Glasgow and South-Western Railway.

The paper was illustrated by sections and plans, and by a large series of bones of animals and shells of mollusca found in the mound.

Some remarks on the subject were made at the close by various members.

Society's Rooms, 207 Bath Street, 9th April, 1891.

Mr. John Young, F.G.S., *Vice-President*, in the Chair.

Mr. Joseph Sommerville exhibited specimens of Garnierite, a Silicate of Nickel, found in Serpentine, in New Caledonia, and imported for commercial purposes, there being a considerable demand for the metal. He remarked that this mineral, named after its discoverer, Garnier, was first found in the Island of Noumea, but has since been met with in Australia and in some parts of North America.

Mr. D. C. Glen, F.G.S., also exhibited a number of specimens of Nickel ore in the rough state, and of the crude and the pure metal.

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Mr. JOSEPH SOMMERVILLE exhibited a simple form of Specific Gravity Balance for testing rocks and minerals, and showed its practical working.

The CHAIRMAN (Mr. Young, read a paper entitled "Notes on a small Group of Carboniferous Foraminifera found in the Lower Limestone Shales of the Muirkirk district in Ayrshire, with a list of the Genera and Species found in the Coalfields of Western Scotland" [see page 313], in which he stated that these minute organisms existed in a finer state of preservation and in greater numbers in the rocks of the Muirkirk district than in any district of Western Scotland where they had yet been found. To show their minute forms and structure he exhibited, under the Society's microscope, a series of transparent sections prepared by himself, in which were seen several new and undescribed species. The group has been studied by Dr. Carpenter, by Professor T. Rupert Jones, and by Dr. Brady, the latter having published a monograph on it; but doubtless many new forms yet remain to reward the diligent observer, and here, Mr. Young observed, there is a good field for some of the younger members of the Society to work up.

Mr. ROBERT DUNLOP read "Note on a 'Wash-out' in a Shallow Pit of the Drumshangie Coal Company, near Airdrie." [See page 320.]

SOCIETY'S ROOMS, 207 BATH STREET, 7TH MAY, 1891.

Mr. WILLIAM JOLLY, F.G.S., *Vice-President*, in the Chair.

Mr. JOHN YOUNG, F.G.S., exhibited, on behalf of Mr. D. C. Glen, F.G.S., who was unable to be present, a selection of Minerals, Polished Gems, and Cut Stones, from the portion of his magnificent collection which had been lent to the East End Exhibition, Dennistoun, and from which it had just been returned. The selection comprised many and fine examples of Chalcedony, some with dendritic markings; Agate in the ringed forms of Onyx and Sardonyx; Cameo, Egyptian Jasper, Crocidolite, Silicate of Copper; and numerous other rare and precious specimens. Mr. Young described a number of the more notable examples, and stated that, growing from a very small nucleus formed about the commencement of the Society's foundation [1858], Mr. Glen's collection had now become unrivalled amongst private collections in the West of Scotland, if not in a wider area. He regretted much, in common with many others, that so far as exhibited, it had not been displayed to greater advantage in the late Exhibition, of which it ought certainly to have formed one of the most attractive features. The fact was, however, it had been so carefully bestowed in one of the lower and most inaccessible rooms, that visitors in general were unaware of its existence.

The CHAIRMAN (Mr. Jolly) remarked that he had never before met with such a private collection, and regretted that its value for educative purposes had not been sufficiently realized by the late Exhibition committee. Mr. Ruskin, one of whose most fascinating works, "Deucalion," was largely devoted to the study of Chalcedonies and Agates, had given

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his wonderful collection of these minerals to the nation, and any of the members who had the chance of being in Sheffield should not omit to see it at its permanent home in that town.

Mr. ROBERT DUNLOP exhibited a small collection of Fossil Fish. One of the specimens shewed a curious forgery, the head of one species being deftly attached to the body of another, as was first pointed out by Dr. R. H. Traquair of the Science and Art Museum, Edinburgh. Such manufactured specimens of fossil organisms are by no means unknown, as they are got up by unscrupulous dealers for the purpose of being palmed off upon young or inexperienced collectors.

The HON. SECRETARY (Mr. Murdoch) read, on behalf of Mr. James Bennie, of H.M. Geological Survey, a paper entitled "Scenes and Sections in Thornton Quarries, East Kilbride, in 1868." [See page 276]. After describing his various visits to Thornton, and explorations of its fossil-bearing strata, Mr. Bennie said that his more special purpose was to point out to the younger generation of collectors the opportunities still offered in this locality for further examination and discovery.

A short discussion on various subjects brought up in the paper was taken part in by several members.

The CHAIRMAN, before closing the meeting, spoke of the issue of part i., vol. ix., of the Society's *Transactions*, and said that from a cursory examination it appeared to him to be one of the most valuable parts yet issued, and one likely to add to the Society's reputation for good and honest work. He concluded by proposing a hearty vote of thanks to the editor (Mr. Murdoch), which was unanimously agreed to.

SOCIETY'S ROOMS, 207 BATH STREET, 28TH MAY, 1891.

Mr. JOHN YOUNG, F.G.S., *Vice-President*, in the Chair.

Mr. Robert Starke, Solicitor, 43 West Regent Street, was elected an Ordinary Member.

Mr. WILLIAM JOLLY, F.G.S., *V.P.*, gave an account of an excursion lately taken by the members to Croy Hill and Barr Hill, on the line of the Roman Wall, near Kilsyth, and spoke of some of the more interesting geological features met with during the day's ramble.

Mr. JAMES WHITE, *Hon. Librarian*, exhibited specimens of several species of Carboniferous Plants belonging to the genus *Lepidodendron*, from shale, near Kilsyth, and made some remarks on their occurrence.

Mr. MATHEW BLAIR exhibited specimens of Gold Ore from California, of Silver Ore from Nevada and Arizona, and of Silicated Fossil Wood from a buried river channel met with 200 feet below the surface in Nevada. He also made some remarks upon them, being followed by the Chairman (Mr. Young), and Mr. D. C. Glen, F.G.S.

Mr. DUGALD BELL gave an abstract of a paper lately read by Mr. Percy F. Kendall, F.G.S., before the Literary and Philosophical Society of Manchester, upon the origin of certain boulders found in the Isle of Man.

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Several of these of a fine-grained granite containing riebeckite, from the Isle of Man, and one from Moel Tryfaen, resemble in character the riebeckite rock of Ailsa Craig rather than that of Mynydd Mawr. Their occurrence confirms the conclusions arrived at from the evidence afforded by the striæ, that ice came out of the Firth of Clyde into the Irish Sea, and must have risen 250 feet between Ailsa Craig and Moel Tryfaen.

Mr. DUGALD BELL then read a paper "On a Glacial Mound in Glen Fruin, Dumbartonshire," describing it as one of the most continuous and characteristic moraines which he had met with in the West of Scotland. [See page 345]. The paper was illustrated by sketches, maps, and photographs. An interesting discussion which followed was taken part in by various members.

PROCEEDINGS FOR SESSION 1891-92.

(34TH SESSION.)

SOCIETY'S ROOMS, 207 BATH STREET, 15TH OCTOBER, 1891.

Mr. JOSEPH SOMMERVILLE, *Vice-President*, in the Chair.

The CHAIRMAN congratulated the members on the opening of a new session, hoping that they had come back from their summer rambles in renewed health and spirits, and that many results in the shape of papers and specimens would be forthcoming at future meetings.

He then alluded to the death of one of the Society's oldest members—Mr. Walter Burns—who had been long an office-bearer and an occasional contributor to the *Transactions*. It was agreed that a note of his death should be recorded in the minutes, and that an expression of the regret of the members should be forwarded to Mrs. Burns.

A Concretionary Nodule of Carbonate of Lime, remarkably resembling an organic form, from schistose rock near Troon, was sent for exhibition by Mr. John Kirsop.

Mr. JAMES WHITE, *Hon. Librarian*, exhibited a number of Coral specimens from the Lias beds of Skye.

Mr. WHITE then read a paper entitled "A Glimpse of the Irish Highlands," which was illustrated by numerous specimens of rocks and fossils.

Some discussion on the points raised by the author followed, and was taken part in by the Chairman (Mr. Sommerville), Mr. John Young, F.G.S., Mr. Dugald Bell, and other members.

Mr. D. C. GLEN, F.G.S., then gave his Report as delegate to the recent (Cardiff) meeting of the British Association, which had been a very successful and enjoyable one.

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SOCIETY'S ROOMS, 207 BATH STREET, 12TH NOVEMBER, 1891.

ANNUAL GENERAL BUSINESS MEETING.

Mr. WILLIAM JOLLY, F.G.S., *Vice-President*, in the Chair.

The HON. SECRETARY (Mr. Murdoch) read the Report of the Council upon the business of the past year. [See page 436].

The HON. TREASURER (Mr. John Wight, C.A.) read the Financial Statement. [For the Abstract of Accounts, see page 443].

The HON. LIBRARIAN (Mr. James White) submitted his Report on the work of the Library during the year.

A unanimous vote of thanks was then awarded to the Honorary Secretaries, Treasurer, and Librarian for their services in the work of the Society.

The election of office-bearers to fill the vacancies in the Council was then proceeded with, the following being the result:—

As Vice-President, Mr. John Smith, Kilwinning.

As Members of Council, Messrs. David Forsyth, Joseph Sommerville, D. C. Glen, F.G.S., James Steel, C. T. Dobbie, and John Dougan.

As Auditors, Messrs. David Pearson and John Main, F.G.S.

Mr. JAMES THOMSON, F.G.S., gave notice of motion that a sum of £8 should be devoted to the purchase of books for the Library.

A series of specimens of Phosphate of Lime in its nodular, earthy, compact, and crystalline forms, sent for exhibition by Mr. John Kirsop, was described by Mr. John Young, F.G.S., who stated that these varieties of the mineral vary considerably in the percentage of phosphate they contain, but that one and all, after being chemically treated, become the "superphosphates" of commerce, so generally known as powerful stimulants of vegetable life.

Prof. JOHN DOUGALL, M.D., St. Mungo's College, Corresponding Member, read a paper upon "The Leaf-caves of Mull" [see page 286], illustrated by a series of specimens from the Leaf-beds, which he had personally obtained from the rock *in situ*.

Mr. JOHN HOWAT also exhibited a small collection of Miocene plant remains which he had obtained in Mull a number of years ago.

Remarks upon various points touched on in the paper were made by Messrs. John Young, F.G.S., James Thomson, F.G.S., Joseph Sommerville, D. C. Glen, F.G.S., and the Chairman (Mr. Jolly).

SOCIETY'S ROOMS, 207 BATH STREET, 10TH DECEMBER, 1891.

Mr. JOHN SMITH, *Vice-President*, in the Chair.

The following gentlemen were elected Ordinary Members:—

Mr. James Rennie Barnett, Lilybank House, Johnstone.
Mr. John Carson, 6 Doune Quadrant, Kelvinside.
Mr. Charles Cowie, Merchant, Rangoon, Woodend, Partick.
Mr. William Hodge, 27 Montgomerie Drive, Kelvinside.

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Mr. James Neilson, High Crosshill, Rutherglen.
Mr. John Grant Sharp, 127 Great Hamilton Street.
Mr. J. Parker Smith, M.P., Jordanhill, Partick.

The Hon. Secretary (Mr. Murdoch) read, on behalf of Dr. David Ross, a short notice of the late Mr. Daniel M'Millan, long a member and office-bearer of the Society, as follows:—

Last week there passed away, at the age of 64, Mr. Daniel M'Millan, a member of this Society, and formerly one of the vice-presidents. He was a keen lover of nature, and often took part in the excursions of this Society as well as those of the Archæological Society, of which he was also a member. Born in the Campbeltown district, he was early trained for the profession of teaching, in which he attained great success, being successively employed in the Training College, Edinburgh, as House-master in Neilson's Institution, Paisley, and as Head-master of Alexander's Endowed School, Glasgow. From the last position he retired only a few years ago. He resided for some years in Helensburgh, where he filled the office of Councillor with great acceptance. Of commanding presence, clear head, methodical habits, and fluent address, his services were much appreciated by the various educational societies in Scotland. Two years ago he was invited to become the President of the Educational Institute of Scotland; but failing health compelled him to decline that honourable but onerous position. He became a member of this Society in 1878, and was for a term of years a member of Council and Vice-president.

Mr. John Young, F.G.S., spoke of the recent death of another old member of the Society—Mr. James Dairon, F.G.S.—who had been an office-bearer for a number of years and an occasional contributor to the *Transactions*.

Mr. D. C Glen, F.G.S., spoke of his own recollection of the deceased members, and proposed that a vote of sympathy with the widow and surviving relatives of each should be passed, and an extract from the minutes forwarded by the Secretary. This was unanimously agreed to.

Mr. Joseph Sommerville exhibited a number of fine specimens of Rocks and Fossils from Canada, collected by himself during a recent visit, including Black Labradorite (Felspar), Nicolite, Asbestos, and Banded Agate. Mr. Sommerville also exhibited a collection of Photographs of Indian life.

The Chairman (Mr. John Smith), read a paper on "The Sand-hills of Torrs Warren, Wigtonshire." [See page 293.]

A discussion followed, being taken part in by Messrs. John Young, F.G.S., D. C. Glen, F.G.S., Dugald Bell, James Neilson, J. B. Murdoch, and other members.

Society's Rooms, 207 Bath Street, 14th January, 1892.

Mr. John Young, F.G.S., *Vice-President*, in the Chair.

In opening the meeting the Chairman expressed a hope that during the coming year Death would not be so busy amongst their ranks as he had

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been during 1891, for since the end of last session the Society had lost no less than five of its more prominent members, the last to be taken away being the well-known and much-esteemed Archibald Robertson.

There had also lately been taken from us an honorary member, eminent in the geological world, Sir Andrew C. Ramsay, long known and esteemed as Director-General of the Geological Survey of Great Britain and Ireland.

The HON. SECRETARY said that the Council had agreed that, subject to the approval of the members, a letter of congratulation to Sir William Thomson, President of the Society, on his accession to the peerage [under the title of Baron Kelvin], should be sent, and moved accordingly. The motion was unanimously agreed to.

A motion to devote £8 from the funds towards the purchase of books for the Library was made by Mr. James Thomson, F.G.S. Mr. John Wight, C.A., Hon. Treasurer, seconded, upon the condition that the expenditure should, if possible, be restricted to £5, and, with this alteration, the motion was agreed to.

Professor JOHN YOUNG, M.D., read a "Notice of the Life and Work of Sir A. C. Ramsay." [See page 256].

Mr. A. B. MOTHERWELL exhibited (1) a number of mineral specimens, including Malachite, Argentiferous Lead, Oxide of Copper, and Calcite Crystals, from Cairns, the most northernly town in Queensland. He also showed (2) Mica Schist, showing exfoliation from lateral pressure, and (3) Strontianite, from Argyllshire.

Mr. WILLIAM JOLLY, F.G.S., read, on behalf of Dr. David Forsyth, Leeds, a paper entitled "The Geology of the Carsphairn District of Kirkcudbrightshire." [See page 376].

The paper was illustrated by a large series of maps, diagrams, sections, and sketches, and a collection of rock and fossil specimens. Some remarks on the district and the points touched upon by the author were afterwards made by the chairman (Mr. Young), Messrs. James Thomson, F.G.S., Dugald Bell, and other members.

SOCIETY'S ROOMS, 207 BATH STREET, 11TH FEBRUARY, 1892.

Mr. JOHN YOUNG, F.G.S., *Vice-President*, in the Chair.

Mr. William Hodge, Craigvinean, Pollokshields, was elected an Ordinary Member.

The CHAIRMAN (Mr. John Young, F.G.S.) read "A Note upon a peculiar variety of Sphærosiderite, a carbonate of iron, from the South Hill, Campsie," and exhibited specimens of the rock, also transparent sections under the Society's microscope. Mr. Young stated that this ironstone is found in connection with the strata which underlie the lower coals and limestones of the Campsie district, forming a thin band, apparently made up of an aggregation of spherical particles more or less rounded and averaging one-sixteenth of an inch in diameter. In a transparent section these particles

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are seen to be composed of zonal layers of carbonate of iron segregated round a centre, in varying shades of brownish colour which mark off the layers distinctly from one another. The spheres are further distinguished by a concentric crystalline structure radiating from the centre. This combination of zonal and crystalline structure forms a lovely object for examination under the microscope, and has not apparently as yet been noted in connection with any of the other ironstones in Scotland. Its formation may probably have been due to thermal heating of the strata through igneous action.

Mr. ROBERT DUNLOP read, on behalf of Mr. Robert M'Laren, H.M. Assistant Inspector of Mines, a note upon "A Reverse Fault in Kiltongue Coal at Drumshangie Colliery, Airdrie" [see page 390], which was illustrated by several sections. At its close remarks were made by several members, who agreed in observing that there is a more frequent occurrence of reverse faults than has been generally supposed, although they are hardly mentioned in the text-books.

Mr. JOHN MAIN, F.G.S., exhibited, by the oxy-hydrogen lantern, an extensive series of Photographs of the Moon's Surface, showing numerous evidences of Volcanic Action on a large scale, and also other views of corresponding terrestrial appearances.

An interesting discussion followed, being taken part in by the Chairman (Mr. Young), Drs. Ross and Sloan, Messrs. Dunlop, Sommerville, and other members.

SOCIETY'S ROOMS, 207 BATH STREET, 10TH MARCH, 1892.

Mr. JOHN YOUNG, F.G.S., *Vice-President*, in the Chair.

Mr. DUGALD BELL, F.G.S., read a paper "On the Alleged Proofs of Submergence in Scotland during the Glacial Epoch.—I. Chapelhall, near Airdrie." [See page 321.]

A discussion upon various points embraced in the paper was taken part in by Messrs. Robert Dunlop, James Thomson, F.G.S., James Neilson, James Steel, and the Chairman (Mr. Young).

SOCIETY'S ROOMS, 207 BATH STREET, 14TH APRIL, 1892.

Mr. WILLIAM JOLLY, F.G.S., *Vice-President*, in the Chair.

Mr. A. B. MOTHERWELL exhibited specimens of Copal from near Bonny, on the Gold Coast of West Africa. He stated that this substance, imported for varnish-making and other purposes, is a sub-fossil gum, the product of a tree, *Trachylobium Hornemannianum*, of the old African forests, and is found at a depth of from 4 to 6 feet below the surface of the existing soil. Mr. John Young, F.G.S., also made some remarks upon the specimens.

Mr. JAMES NEILSON showed a number of specimens of Red Zeolites from the Lesser Cumbrae, in the Firth of Clyde, and read a short paper upon

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their occurrence and distribution, entitled, "A Visit to the Island of Little Cumbrae, with some notes on its Minerals." [See page 373.]

The CHAIRMAN (Mr. Jolly) said that this interesting island might form a suitable locality for one of the Society's excursions next spring or summer.

Mr. M. BLAIR exhibited specimens from two large boulders near King's Cross, Arran. He remarked that the erratic blocks in this neighbourhood are very numerous, but are nearly all local, being traceable to Goatfell, 10 miles north, from which they must have crossed two deep valleys and a ridge. The two large blocks referred to are totally different from any Arran rock. From a description given by Professor Judd, in a paper on "The Secondary Rocks of Scotland" in the *Quart. Jour. Geol. Soc.*, of certain beds in the Island of Raasay, Mr. Blair thought that the rock might be found there *in situ*, and he had brought up the specimens in the hope that some of the members might be able to identify them. Prof. Judd's description is as follows:—"Conglomerates (formed of rounded or sub-angular fragments of white or purple quartzite, of Torridon sandstone, and of compact or sub-crystalline limestone) alternating with irregular lenticular beds of coarse micaceous sandstone, into which the conglomerates insensibly graduate."

The CHAIRMAN said he would endeavour, through the good offices of the schoolmaster in Raasay, to obtain specimens of the rock *in situ*, so that they might be compared with these Arran boulders.

Mr. JOHN YOUNG, F.G.S., read a joint paper by Prof. John Young, M.D., &c., and himself, "On the Root-fibres and other Processes found attached to Fronds of Carboniferous *Fenestella* and other Bryozoa." The authors in this paper referred to certain peculiar branching, fenestrated structures which they had found rooted on the fronds of *Fenestella*, and which were, apparently, as yet undescribed. These processes, when examined in thin sections, showed the same kind of finely-striated and minutely-perforated structure as that seen in the walls of the organisms from which they had grown, the true organic connection between the two being clearly seen in several of the specimens. Their external characters are, however, very dissimilar in appearance, there being no cells in the walls of the processes now described. The specimens exhibited were found in the marine limestones and shales of the Campsie, Carluke, Muirkirk, and Beith districts. The authors referred to a former joint paper, *Quart. Jour. Geol. Soc.*, vol. xxx., page 684, in which they figured and described other forms of root-like processes which they had found adherent to other fenestrated Bryozoa. Some writers had pronounced those to be distinct organisms under the name of *Palæocoryne*, but the present authors had at the time spoken of proved them to have a true organic connection with the Bryozoa on which they had grown, and later discoveries had only confirmed their statements of 1874.

The paper was illustrated by specimens, microscopic sections, and enlarged drawings of the structures.

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SOCIETY'S ROOMS, 207 BATH STREET, 12TH MAY, 1892.

Mr. JOHN SMITH, *Vice-President*, in the Chair.

A most successful enlargement of a Photographic Group of the Members present at the excursion to Daleville, Braidwood, on 21st June, 1890, was presented by Mr. William Sinclair, by whom it had been originally taken, and who was cordially thanked for his gift.

The HON. SECRETARY (Mr. Murdoch) stated that since the issue of the excursion card for the season two extra excursions had been arranged, as follows:—

On 2nd July, to Bonnybridge and the Roman Wall—Mr. William Jolly, F.G.S., conductor; and on 9th July, to Balmaha, Lochlomond—Mr. James Anderson, conductor.

The HON. SECRETARY having stated a proposed arrangement by which the Transactions, &c., of Foreign Societies received in exchange by the Society were to be transferred to the Mitchell Free Library, Mr. James Thomson, F.G.S., moved that such an arrangement should forthwith be carried out. The motion was seconded by Mr. John Young, F.G.S., and unanimously agreed to. It was remitted to the Library Committee to take the necessary steps.

Messrs. James S. Cherry, Trefoil Avenue, Shawlands; Alexander Gardner, Architect, 192 Hope Street; and Alexander Laird, Merchant, 63 Wilson Street, were elected Ordinary Members.

The HON. SECRETARY (Mr. Murdoch) read, on behalf of Dr. Forster-Heddle of St. Andrews, a paper "On Pectolite and Okenite from new Localities: the former with New Appearances." [See page 241.]

Rev. A. S. WILSON, M.A., B.Sc., North Queensferry, read a paper entitled "Notes on the Geology of Fife" [see page 392], in which he gave an interesting account of the rocks of the "Kingdom," illustrating his remarks by maps and sections and by a number of rock and fossil specimens.

Remarks were afterwards made by Messrs. John Young, F.G.S., Mr. James Thomson, F.G.S., and other members.

Mr. DUGALD BELL, F.G.S., read "A short Preliminary Note on some Glacial Mounds in the neighbourhood of Lochgoil and Lochlomond." After alluding to the remarkable moraine in Glen Fruin, which he had brought under the notice of the Society rather more than a year previously, he proceeded to mention a few other accumulations of a similar kind, some of which had doubtless been already observed, though he was not aware of their having been previously notified or described.

These occur (1) at Lochgoil, near Carrick Castle, where is seen a long line or double line of large boulders and debris, extending for some distance up the glen; (2) at the head of Lochlomond, near Ardlui, shewing both lateral and terminal moraines; (3) near Balmaha, on the east side of Lochlomond, not far from its southern end, and extending in more detached portions towards the foot of the loch. The examples at (1) and (2) indicated that the respective glaciers had made a long pause at these points, and that there had been no subsequent submergence.

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He then referred to the well-known instances in Glen Messan and Glen Cloy, and pointed out the important evidence which these heaps of unassorted glacial debris, found at no great height above the sea-line, furnished as to the extent and prevalence of the ice at a time when the land stood not far from its present level. He also spoke of their bearing generally on the question of the "Great Submergence."

A short discussion on various points touched upon in Mr. Bell's paper followed, being taken part in by several members. The chairman then declared the 34th session of the Society to be closed, and expressed a hope that the members would meet in the following October to carry on the work with renewed vigour.

REPORT OF THE COUNCIL FOR 1887-88.

[Read at the Annual General Business Meeting, 8th November, 1888.]

The Council have again the pleasing duty of submitting to the members their report upon the work of the past session, 1887-88, showing that the affairs of the Society have proceeded smoothly and satisfactorily.

MEMBERSHIP.—The membership roll has not been maintained at such a high level as could be wished, and the Council hope that members will exert themselves in this direction and bring in additions to replace the losses caused by death and removal from the district.

FINANCES.—As to these your Hon. Treasurer, Mr. Wight, will present his report, which will be favourable. [The Abstract of Accounts will be found at page 440.]

MEETINGS.—These were nine in number, and there was also a special meeting to hear a paper by the President, Sir William Thomson, F.R.S., on "Polar Ice-caps and their influence in changing Sea-levels." It was held in the Large Hall, 207 Bath Street, kindly lent by the House Committee, and there was a good attendance of members and their friends as well as of members of other scientific societies, to all of whom invitations had been given. [See vol. ix., part ii., p. 322.] The ordinary meetings were fairly, some largely, attended, and there were many papers of importance and exhibitions of specimens. [Details of these will be found in the *Transactions*, vol. viii., part ii., pages 350-58, and many of the papers will be found in the same part *in extenso*.

The TRANSACTIONS.—A new part is now nearly all in type.

The EXCURSIONS of the season were as follows:—

Cathkin, on Saturday, 14th April, 1888, conducted by Mr. Walter Burns, when a visit was paid to the fine exposures of columnar traps in a quarry near Burnside, and afterwards to the Cathkin quarries; near the top of the hill were found fine specimens of volcanic ash, saponite, bowlingite, &c., &c. Some of the party proceeded across the hill to East Kilbride, taking train homewards late in the evening.

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Barrhead, on Saturday, 28th April, under the guidance of Mr. D. C. Glen, F.G.S. The party first proceeded to Boyleston quarry workings in the contemporaneous traps, and were fortunate in finding some good specimens of native copper, analcite, prehnite, and other minerals. A number of the members were afterwards entertained at tea by Mrs. Glen, of Carlibar, where a pleasant evening was spent.

Corrieburn, on Saturday, 12th May, Mr. John Young, F.G.S., conductor. The excursionists proceeded to Gavell Station on the Kilsyth railway, thence walking up the slopes of the Campsie Fells to the interesting sections exposed at Corrieburn of the Carboniferous limestones, shales, ironstones, &c., with a heavy capping of Boulder-clay. Some of the old workings were afterwards visited.

Beith, on Saturday, 2nd June, conducted by Mr. Robert Craig, when the fossiliferous shales and volcanic ash-beds were intended to be visited, but the weather unfortunately was so bad that none of the members turned out.

Milngavie and Mugdock, on Saturday, 16th June, under the guidance of Mr. C. C. Bone, C.E. This excursion was taken principally to visit the spoil-heaps and tunnels along the line of the new Glasgow water supply. A number of fine specimens of volcanic rock were obtained by members.

Mid-Calder, on Saturday, 30th June, a joint-excursion with the Edinburgh Geological Society, under the leadership of Mr. James Melvin, *V.-P.*, took place, and was very successful, there being a large contingent of members from both societies.

An extra excursion which had been proposed to Balmaha, Lochlomond, did not take place, owing to the difficulty of arranging for the loch steamer to call at Balmaha at suitable times for the party.

Loss of Members.—As in every successive report, the names of some of our members have to be withdrawn from the roll through death and other causes. The most notable loss to the Society in this connection is that of Mr. David Sandeman, who had been long a member and for some years an office-bearer. Though not a contributor to the *Transactions*, he had always the interests of the Society at heart. Those of the members who cared to visit Mr. Sandeman at his home in Lenzie were sure of a hearty welcome, and an inspection of his varied collection of minerals and fossils.

The International Exhibition.—The year 1888 will long be notable in Glasgow annals for the opening and extremely successful career of the great show, which for a number of months has proved such a source of attraction to inhabitants and strangers equally. Fortunately few of the meetings of the Society took place after its opening, so that the superior attractions of the Exhibition did not interfere with the work.

Though the great collection did not contain much which was distinctly geological, there were many things which were at least kindred to the

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science, such as the exhibits of industrial minerals and metallic ores, precious stones, diamond cutting, &c., &c. A very fine collection of Jade in specimens and ornamental pieces, the property of R. Novar Ferguson, M.P., which was shown in a cabinet placed in the southern approach, did not attract the attention which its merits undoubtedly deserved.

REPORT OF THE COUNCIL FOR 1888-89.

[Read at the Annual General Business Meeting, 14th November, 1889.]

The Council have again to lay before the members a report upon the work of the past year, the thirty-first of the Society's existence.

MEMBERSHIP.—Owing to the usual causes the membership roll has slightly diminished, which is a source of regret and anxiety to your Council, as they had hoped that the appeal made to members last year at this time would have resulted in a substantial increase.

If members would only take this matter into their serious consideration there is no reason to suppose that each one could not secure at least one new additional name either as a life- or ordinary member, and the Council hope to see that during the current session there will be a considerable accession to the roll.

The FINANCES, as your Hon. Treasurer, Mr. Wight, will report to you, show that the Society is in a solvent condition with a considerable balance in hand. [For the Abstract of Accounts see p. 441.]

The MEETINGS of the past year were nine in number—there being no special meetings—and were attended by about the usual average number of members. Plenty, sometimes a superabundance, of material was brought before them, and on several occasions papers and discussions had to be postponed to a succeeding meeting. Regarding this subject it may be pointed out to contributors of specimens or papers that if they would give some previous indication of the time they would occupy, the arrangement of the billets for the meetings would be more satisfactorily accomplished.

Nearly all the papers read during the session were illustrated by specimens, diagrams, &c., and the Council hope that most of these papers will soon be published. [See *Transactions*, vol. ix., part i, pp. 226-232.]

Two important papers, those by Mr. H. M. Cadell, F.R.S.E., and Mr. Robert Kidston, F.G.S., were delivered in the Large Hall of the Philosophical Society and the Engineers' and Shipbuilders' Society, at 207 Bath Street, and the thanks of the members are due to the House Committee for permission to use it. Members of other scientific societies and their friends were invited to both meetings, and there was a good attendance.

The LIBRARY.—There has been a fair demand for books, but probably a larger addition of new works would increase this demand. Should the state of the funds permit of the necessary expenditure, it is hoped that such an addition may be made.

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EXCURSIONS.—Before the regular excursions for 1889 two special ones were arranged, as undernoted:—

Bowling, on Saturday, 23rd March, 1889, under the conductorship of Mr. W. J. Millar, C.E. On this occasion a visit was made to the excavations in Boulder-clay for the new water-works, where some fine examples of glaciated rock-surfaces were seen. Mr. Millar, who is the engineer for the works, afterwards read a detailed paper to the Society. [See *Transactions*, vol. ix., part i., p. 203.]

Ardrossan New Harbour Works, on Saturday, 6th April, conducted by Mr. Robertson, C.E., resident engineer. On the invitation of Mr. Robertson a large party of the members visited the excavations for the new works and saw some fine exposures of sandstones, shales, mudstones, and intersecting trap dykes. They also inspected the process of concrete building for the harbour walls, foundation-laying under water, &c.

The EXCURSIONS of the session were as follows:—

Cambuslang and Cathkin, on Saturday, 13th April, conducted by Mr. Walter Burns. The columnar traps and Carboniferous sandstones were first inspected, and then the party climbed Cathkin Braes to the volcanic ash-beds exposed in the old quarries near the top of the hill.

Irvine and Kilwinning, on Saturday, 27th April, conducted by Mr. John Smith. The principal part of the day's walk was to the Raised-beach beds and blown sands on the banks of Irvine water, the return journey being made *via* Kilwinning, where several exposures of Carboniferous strata were inspected.

Mugdock (Milngavie), on Saturday, 11th May, conducted by Mr. C. C. Bone, C.E. The object of the excursion was to inspect the excavations and tunnelling for the extension of the Glasgow water-works. The spoil-heaps afforded many specimens of volcanic ash, peridotite, dolerite, &c., &c.

Airdrie, on Saturday, 25th May, conducted by Mr. Robert Dunlop. An inspection was made of basalt and dolerite, finely showing spheroidal decomposition, and a remarkable exposure of a peat bed under Boulder-clay.

Cadzow Forest and Avon Water, on Saturday, 8th June, Mr. John Young, F.G.S., conductor. The members on this occasion visited the remains of the old Caledonian Forest, and saw to great advantage the Duke of Hamilton's herds of the indigenous white cattle. In the rocky banks of the Avon water some splendid exposures of Carboniferous strata were observed.

South Queensferry and the Forth Bridge, on Saturday, 22nd June, conducted by Mr. Henry M. Cadell, F.R.S.E., Hon. Sec. of the Edinburgh Geological Society. This being a joint-excursion with the members of the Edinburgh Geological Society, and

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special permission having been obtained to visit the works, workshops, and the bridge itself, a very large party of members and their friends took advantage of the occasion. Leaving Queen Street Station at 1 p.m., the party changed carriages at Ratho, where they joined the Edinburgh contingent. Reaching South Queensferry about 3 p.m., they proceeded to inspect, under the guidance of some of the resident engineers, the wonderful structure now in process of being thrown across the Forth, and several of the workshops with their complicated machinery and labour-saving appliances. A considerable number of those present climbed to the top of the southern cantilever. After leaving the bridge, many of the members made an inspection of the calciferous sandstones, shale beds, and trap rocks lying along the southern shore. The party then taking train for Edinburgh proceeded to Howe's hotel, where a high tea was provided. Afterwards several toasts were given, including the prosperity of the two Societies, the health of the office-bearers and the conductor (Mr. Cadell). At 8.20 p.m. the Glasgow members left the Waverley Station, reaching Glasgow at 10.30 p.m., after a most enjoyable trip.

A new departure was taken this year in the arrangement of a walk to Hamilton Hill on Monday evening, 3rd June, to visit the fine exposures of Boulder-clay to be seen there, under the guidance of Mr. James White, *Hon. Librarian.* This excursion was much approved, and has since led to evening excursions becoming a regular feature of the season's programme.

On Saturday, 6th July, an extra excursion to Balmaha, Lochlomond, was arranged, under the conductorship of Mr. James Anderson, and was taken part in by a number of members. The conglomerate beds of the Old Red Sandstone and the dolomitic limestones were inspected, but time did not permit of anything like a full examination, and a wish was expressed that another opportunity might be given of visiting this most interesting locality.

The Transactions.—As this report shows, several valuable papers are ready, and, if possible, the printing of a new part to contain the papers of the last and the present session will be begun in January next.

Geological Photography.—From the spread of photography, owing to the comparative ease with which pictures are now taken, photographing of subjects of geological interest has become much more practicable than in former years. An invitation has been given to this Society to take part in such work by the Corresponding Societies Committee of the British Association. Your Council have looked favourably upon the suggestion, and hope that members who are practically acquainted with the subject will come forward to take part in the proposed work. Many fine rock-sections—such as are seen in quarry faces, railway cuttings, &c.—which may disappear after short intervals, might be advantageously photographed for preservation and future reference.

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Loss of Members.—In all societies each year brings its own list of names of members to be added to those who have joined the *great majority*, and the one now spoken of forms no exception to the rule. Several members who were known and esteemed have been taken from amongst us, and prominent amongst these stands the name of Mathew Blair, of Paisley, who for some years served as a member of your Council. Devoted to the science, Mr. Blair was a hard working, observant student, who, had he been longer spared to us, would doubtless have done still better work than he had accomplished in the past.

REPORT OF THE COUNCIL FOR 1889-90.

[Read at the Annual General Business Meeting, 13th November, 1890.]

The Council have again to submit their report upon the work and events of the past session, the thirty-second of the Society's existence.

Membership.—For some years past it has been necessary to call attention to the fact that there has been some diminution in the roll of membership. A certain proportion of names have to be withdrawn each year owing to deaths and resignations, and the accession of new members ought to be at least as great. This has, however, not lately been the case, though for several years a form of proposal, with a request that it should be returned with a new member's name filled in, has been sent to each member. The Council would therefore ask members to make a stronger effort in the required direction.

Finances.—As on previous occasions your Hon. Treasurer, Mr. John Wight, C.A., will submit his report. It is not necessary to go into detail here, further than to say that, though upon the whole favourable, the funds of the Society are so dependent upon the membership that what affects the one re-acts upon the other. [For the Abstract of Accounts see p. 442.]

Meetings.—During the bygone session many papers and notes upon specimens of interest were submitted to the Society at its meetings, which were nine in number. [Particulars as to these will be found in the *Transactions*, vol. ix., part i., pp. 233-239.]

Excursions.—The excursions of the session were as follows:—

The Hunterian Museum, on Saturday, 12th April, 1890, under the conductorship of Mr. John Young, F.G.S., and on the invitation of Professor John Young, M.D. Those who attended were delighted with their visit, but as on a single occasion only the merest glance at the collection can be taken, a hope was expressed that further opportunities might be afforded the members of studying groups of minerals or fossils in detail.

East Kilbride, on Saturday, 26th April, under the guidance of Mr. James Anderson. This excursion took place on a fine afternoon, and when the cement-stone quarries and shale heaps were

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visited, a number of interesting fossils were collected. The party after leaving East Kilbride walked to Bogton sandstone quarry, and to Braehead limestone quarry, and at Clarkston took train to Glasgow.

Nitshill, Darnley, and Barrhead, on Saturday, 10th May. Owing to the very heavy rainfall in the morning only a very limited party came out by train, and in the absence of Mr. D. C. Glen, who was prevented from attending, Mr. Murdoch, *Hon. Sec.*, conducted the party. Leaving the train at Nitshill, they first visited the sandstone quarry in the Millstone grit, worked by Messrs. Stevenson & Baird. The upper stratum, containing numberless annelid borings, was observed, also large numbers of travelled blocks which had been removed from the overlying Boulder-clay. At Darnley they inspected Mr. Kirkwood's opencast workings of the Arden cement-limestone, where a number of good specimens of fossils, &c., were got. Owing to the broken weather Barrhead was not reached.

Inverkip, Loch Thom, and Greenock, on Saturday, 24th May, under the leadership of Mr. Wm. Armour, C.E. In this excursion the equivalents of the Ballagan Beds were inspected, and afterwards some exposures of the igneous rocks of the Renfrewshire uplands.

Craigendoran and Helensburgh, on Saturday, 7th June, led by Mr. Dugald Bell. This excursion was planned to visit the cuttings for the new West Highland Railway behind Helensburgh. Some fine sections of Boulder-clay and exposures of schistose rock were met with, but it was apparent that in the course of a few months much better sections would be exposed.

Braidwood, Carluke, on Saturday, 21st June, under the conductorship of Dr. J. R. S. Hunter. This, the annual joint-excursion with the Edinburgh Geological Society, was altered from Carstairs to Braidwood on account of the kind invitation of Dr. Hunter to visit his district. After inspecting the exposures of Carboniferous strata in Braidwood Glen, the party walked to Daleville, where they were most hospitably entertained. General regret was afterwards expressed that too little time remained to inspect the treasures—geological, antiquarian, and bibliographical—stored in such profusion in Dr. Hunter's house. Unfortunately none of the members of the Edinburgh Society were present. A photograph of the party was taken by Mr. William Sinclair. [Mr. Sinclair has since presented an enlargement of this photograph to the Society.]

In addition to the usual excursions, the new departure made last year was followed up by a series of Evening Excursions on Fridays of alternate weeks, conducted by Mr. James White. They were attended with fair success, and seemed to supply a want, felt by those members who cannot

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conveniently leave town on Saturdays. They were three in number, as follows :—

Hamilton Hill, north bank of Forth and Clyde Canal, on Friday, 18th April, to visit the fine section of Boulder-clay, and of the Till or *moraine profonde*, here exposed.

Bishopbriggs, on Friday, 2nd May, to inspect the thick-bedded sandstones, with local unconformity, columnar sandstone, trap dykes, &c.

Giffnock, on Friday, 16th May, to see the thick-bedded sandstones, flaggy sandstones, with numerous annelid burrows, evidences of river erosion, &c.

The Council hope that such a series will be continued next year. The thanks of the members are due to Mr. White and to the other members who kindly volunteered to conduct the various excursions.

The Library.—Your Hon. Librarian, Mr. James White, will submit his report. Few new books have been added during the year, except those received by exchange from other societies. A good many books have been taken out on the nights of meeting, showing that the Library is used by a fair proportion of the members.

The Transactions.—A new part, part i. of vol. ix., is considerably advanced at press. It will contain most of the papers read during the last two sessions, some of these being of much interest and importance.

Death of Members.—From this cause the membership roll has as usual been affected. Amongst those members who have died since last year may be noted Mr. James F. Stewart, long a member of the Society and a frequent attender of both meetings and excursions. Resident in Stirlingshire, he was locally known as the "King of Kippen." He contributed a paper to the *Transactions* "On the Occurrence of Whale Remains in the Valley of the Forth." [See vol. vi., part i., p. 49.]

Dr. Henry Muirhead, of Busheyhill, was a life member of the Society, but his energies were so devoted to the interests of the Philosophical Society that he had little time to spare for geology, though he had always a warm side for the wellbeing of our Society.

The name of Dr. Milne Home, though not a member of the Society, may be mentioned in this connection for his work in general geology, but more especially as regards his papers on the distribution of boulders, in his capacity of Chairman of the Boulder Committee of the Royal Society of Edinburgh. His death will be much regretted by all Scottish geologists.

REPORT OF THE COUNCIL FOR 1890-91.

Read at the Annual General Business Meeting, 12th November, 1891.]

Your Council have again to lay before you their annual report upon the condition and work of the Society during the past year, and regarding which they have upon the whole to speak favourably.

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The MEMBERSHIP has not more than held its own during the year; and as it was a twelvemonth ago less than it had previously been for some time, the Council are disappointed to find that a greater effort has not been made to increase it. Circulars calling attention to this fact, with proposal forms, have been time after time sent to every member, with a very small response. It may therefore be again pointed out how desirable it would be if each member would undertake to find one each additional new member, and how much the objects of the Society would thereby be promoted.

The MEETINGS of the session were nine in number, and had a fair, though not a numerous, attendance. There was brought forward quite sufficient material, both in papers and specimens, to occupy all the available time.

[The titles of the various papers and notices of specimens will be found at pp. 414-422.]

The EXCURSIONS of the spring and summer were as follows:—

Mugdock, on Saturday, 18th April, 1891, conducted by Mr. C. C. Bone, C.E. Sections at cuttings for the great new reservoir of the Glasgow Waterworks were visited, and afterwards the spoil-heaps from the tunnel excavations.

Nettlehirst and Auchenmade, Beith, on Saturday, 2nd May, conducted by Mr. Robert Craig, *cor. mem.* The weather proved so extremely bad that this excursion, planned to visit the Lower Carboniferous limestone strata of this district, did not come off, not a single member having arrived from Glasgow.

Croy and Barrhill, on Saturday, 16th May, conducted by Mr. William Jolly, F.G.S. Sections of intrusive dolerite were seen, and a visit was paid to the gannister beds. A portion of the Antonine Roman Wall was afterwards gone over, and recent investigations were explained by the leader to a numerous party.

Dalry, on Saturday, 30th May, conducted by Mr. John Smith. Some good sections of limestones and shales on Caaf water were seen, also exposures of clayband ironstones, &c.

Murroch and Auchenreoch Glens, on Saturday, 13th June, conducted by Mr. John Renwick. Some fine examples of volcanic disturbance were seen, also of denudation of the calciferous sandstones and limestones. In the latter glen was passed the remarkable dyke which, crossing at right angles, has been breached by the stream. From its bared sides and considerable height it is locally known as the "Gates of Sodom." From here the party struck across the moorland for Dumbarton.

Tory Glen, Chapelhall, on Saturday, 27th June, conducted by Mr. Robert Dunlop. The day being fine a large party, including members of the local Natural History Society, met at Airdrie station and walked to Chapelhall, east of the town. Chapelhall is said to have received its name from the fact that while sinking a pit shaft here the workmen came upon an old chapel and burial ground. In a sandstone quarry a fine section of

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the upper coal measures was seen, containing the main coal seam of 9 feet. About 500 yards south of this occurs the well-known glacial shell-bed, containing arctic shells—the highest present known horizon in this district for their occurrence. Further along the bed of the stream was seen an immense dyke of basalt, which stretches for some distance east and west. A fault here brings the Lower Carboniferous measures to the same horizon as the upper coals—a dislocation of from 1000 to 2000 feet. Continuing up the glen the party examined a number of pot-holes in the rock of the river-bed, smooth, circular cavities of from one to two feet deep. Among the shales here were got some good specimens of teeth and scales of *Rhizodus Hibberti*, one of the Carboniferous sauroid fishes. From this the party proceeded to the Fairy Glen, where Samson's Putting Stone—a dolerite boulder of above 12 tons weight—was seen. The route was then taken via Newhouse to Airdrie where the party were entertained to tea by the Airdrie Natural History Society—Mr. A. B. Motherwell occupying the chair. The Glasgow members then took train for Queen Street Station.

In pursuance of the arrangements made last year, the following Evening Excursions were taken :—

Cessnock New Dock, on Friday, 10th April, conducted by Mr. A. Hamilton, to visit the sections in sand and clay presently exposed.

Hamilton Hill and Sheepmount, on Friday, 8th May, conducted by Mr. James White, Hon. Librarian, to inspect the fine sections of Boulder-clay, &c.

Botanic Gardens and Kirklee, on Friday, 22nd May, conducted by Mr. James White, to visit the cuttings for the new Central District Railway through sandstone, Boulder-clay, &c.

Pollokshaws, on Friday, 5th June, conducted, in Mr. Murdoch's absence, by Mr. James White, to visit the sections of Boulder-clay in the cuttings of the new Cathcart Railway.

The thanks of the members are due to all the gentlemen who kindly took charge of the various excursions of the season, both afternoon and evening.

A proposal was made early in the year that the conductors should draw up a short account of each excursion suitable for publication. This was done in several instances, but it is hoped that in another year the practice will be more generally followed.

For the first time for a number of years no joint-excursion with the members of the Edinburgh Geological Society was arranged. No reason can be assigned for this, unless it be that no excursions were made by the members of that Society this year. It is to be hoped that such pleasant joint gatherings as took place annually for a number of years will again be resumed.

The LIBRARY remains without any material change. It was not thought

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advisable to spend much money in new books, but perhaps a grant may be arranged this year.

The TRANSACTIONS.—The first part of a new volume, part i. of vol. ix., was issued to members in April last. Very complimentary notices of the contents were given in the *Scotsman*, *Glasgow Herald*, and elsewhere, one of them stating that the Society's work, as shown in this part, was second to that of no society out of London.

The FINANCES of the Society will be spoken of in the Treasurer's report. The Abstract of Accounts is printed with the circular calling the present meeting [November, 1891], and will be found at page 443.

THE CORRESPONDING SOCIETIES COMMITTEE OF THE BRITISH ASSOCIATION.—For a number of years past the Society has been placed on the list of Corresponding Societies with the privilege of sending a delegate to the British Association meeting, who is *ex officio* a member of the General Council of that body. It may be shortly stated that the object of this committee is to bring all provincial scientific societies into closer union for the purpose of following out some common subjects of investigation. One of these, open to members of this society, is Geological Photography, and another the recording and preserving of notable Erratic Blocks scattered over the country, and in both of these the Council hope that members will be willing to give their help.

The LOSS OF MEMBERS is unfortunately a line which can never be omitted. Each annual report has to deplore the removal of some good and true friends of the Society, and the present is no exception. Prominent in this connection are the names of two members of Council which occur side by side in one of the committees for the past year, Walter Burns and Daniel Macmillan. Both were interested and active in the Society's work, and both will be much missed from the meetings and excursions, of which they were most regular attenders. Neither of them of very advanced years, they rapidly fell into feeble health, and in a comparatively short time were called away. The Society will not easily find two members more anxious to serve its interests in every way.

Another member removed by death during the session was Mr. Robert Mason, F.L.S., long an office-bearer and a constant attender of the meetings and excursions. He was for many years the honorary secretary of the Natural History Society of Glasgow. Mr. Mason had formed a large collection of minute fossil organisms from the weathering of the Carboniferous limestones and shales of the West of Scotland, mounting them in slides for the microscope. From these he exhibited selections at various meetings. Since his death Mr. Mason's fine cabinet of specimens has passed into the hands of Dr. J. R. S. Hunter of Daleville, Carluke, to become an adjunct of the "Braidwood Collection."

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ABSTRACT OF THE TREASURER'S ACCOUNTS FOR YEAR ENDING 30TH SEPTEMBER, 1888.

CASH ACCOUNT.

RECEIPTS.

Balance—Due by Treasurer at close of last Account,				£4	0	0
Annual Subscriptions—						
Subscriptions for current year,	£72	0	0			
New Members,	6	10	0			
Arrears,	3	0	0			
				81	10	0
Interest on invested funds,				6	12	1
Publications and Catalogues sold,				2	10	5½
				£94	12	6½

EXPENDITURE.

Transactions—Balance of Account,				£2	8	0
Catalogue—Balance of Account,				6	17	0
Rent, Insurance, and Attendance,	£14	11	6			
Collector's Commission and Petty Charges,	4	1	11			
Printing Circulars and Receipt Book,	11	8	3			
Disbursements by Secretaries and Librarian,	9	17	3½			
Palæontographical Society,	1	1	0			
Reporting Sir William Thomson's Lecture,	2	10	0			
				43	9	11½
New Books, Maps, and Binding,				12	2	10
Cash in Bank on Deposit Receipt,	£25	0	0			
Cash in Treasurer's hands,	4	14	9			
				29	14	9
				£94	12	6½

STOCK ACCOUNT.

To Balance to Credit,				£461	14	9
				£461	14	9

By Funds—Corporation Loan,	£170	0	0			
Cash in Bank and in hand,	29	14	9			
				£199	14	9
Property—						
Books,	£165	0	0			
Transactions,	55	0	0			
Furniture and Microscope,	42	0	0			
Fossils (not valued),	0	0	0			
				262	0	0
				£461	14	9

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ABSTRACT OF TREASURER'S ACCOUNTS FOR YEAR ENDING 30TH SEPTEMBER, 1889.

CASH ACCOUNT.

RECEIPTS.

Balance on hand and in Bank at close of last Account,	£29	14	9
Subscriptions for current year, and Arrears (£2),	76	0	0
Interest,	7	2	3
Publications sold,	1	10	7
Balance due to the Treasurer,	2	13	4
	£117	0	11

EXPENDITURE.

Printing *Transactions*,	£56	4	0			
Woodcuts and Plates,	10	1	0			
Articles Reprinted,	10	12	6	£76	17	6
Rent, Insurance, and Attendance,	£12	11	6			
Collector's Commission and petty charges,	3	18	11			
Printing Circulars and Receipts,	9	4	0			
Disbursements by Secretaries and Librarian,	10	1	1			
Subscription to Palæontographical Society,	1	1	0	36	16	6
New Books and Bookbinding,				3	6	11
				£117	0	11

STOCK ACCOUNT.

To Balance to credit,						£414	6	8
						£414	6	8

By Funds Invested, *less* due to Treasurer,				£167	6	8
Property—						
Books,	£165	0	0			
Transactions,	40	0	0			
Furniture,	22	0	0			
Fossils, not valued,	0	0	0			
Microscope,	20	0	0	247	0	0
				£414	6	8

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ABSTRACT OF TREASURER'S ACCOUNTS FOR YEAR ENDING 30TH SEPTEMBER, 1890.

CASH ACCOUNT.

RECEIPTS.

Subscriptions for current year, and Arrears (£3),	£73 0 0
Life Membership Subscription,	5 5 0
Interest,	7 5 2
Publications sold,	1 7 0
Petty Receipts,	0 19 6
	£87 16 8

EXPENDITURE.

Balance due to the Treasurer,		£2 13 4
Rent, Insurance, and Attendance,	£12 10 0	
Collector's Commission and petty charges,	6 4 8	
Circulars, Receipts, and Minute Book,	7 4 0	
Disbursements by Secretaries and Librarian,	8 9 11	
Subscription to Palæontographical Society,	1 1 0	
		35 9 7
Binding Books,		0 17 4
Cash in Bank,	£50 0 0	
Less Balance due to the Treasurer,	1 3 7	
		48 16 5
		£87 16 8

STOCK ACCOUNT.

To Balance to credit,	£718 16 5
	£718 16 5

By Funds Invested, *less* due to the Treasurer,		£218 16 5
Property—		
Books,	£440 0 0	
Furniture, Bookcases, and Microscope,	60 0 0	
Fossils, not valued,	0 0 0	
		500 0 0
		£718 16 5

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ABSTRACT OF THE TREASURER'S ACCOUNTS FOR YEAR ENDING 30TH SEPTEMBER, 1891.

CASH ACCOUNT.

RECEIPTS.

Cash in Bank,	£50	0	0			
Less due to the Treasurer,	1	3	7			
				£48	16	5
Subscriptions for current year, and Arrears (£2),				73	0	0
Interest,				7	16	4
Publications sold,				1	14	3
				£131	7	0

EXPENDITURE.

Plates for *Transactions*,				£7	13	0
Printing *Transactions*, to account,				50	0	0
Rent, Insurance, and Attendance,	£12	10	0			
Collector's Commission and petty charges,	3	15	0			
Printing Circulars, &c.,	6	13	6			
Disbursements by Secretaries and Librarian,	13	8	9			
Subscription to Palæontographical Society,	1	1	0			
				37	8	3
New Books and Binding,				4	8	2
Cash in Bank,	£30	0	0			
Do. in Treasurer's hand,	1	17	7			
				31	17	7
				£131	7	0

STOCK ACCOUNT.

To Balance to Credit,				£701	17	7
				£701	17	7

By Cash in Bank and on hand,				£31	17	7
Funds invested,				170	0	0
Property—						
Books,	£440	0	0			
Furniture, Bookcases, and Microscope,	60	0	0			
Fossils (not valued),	0	0	0			
				500	0	0
				£701	17	7

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THE GEOLOGICAL SOCIETY OF GLASGOW.

(INSTITUTED 1858.)

OFFICE-BEARERS FOR SESSION 1892-93.

President—LORD KELVIN, LL.D., *P.*R.S., &c.

Vice-Presidents.

For Three Years.	*For Two Years.*	*For One Year.*
WM. ARMOUR, C.E.	JOHN SMITH.	WM. JOLLY, F.G.S.

Council.

JNO. YOUNG, LL.D., F.G.S.	J. SOMMERVILLE.	D. BELL, F.G.S.
JAMES ANDERSON.	JAMES STEEL.	JOHN RENWICK.
JOHN MAIN, F.G.S.	C. L. DOBBIE.	DR. S. SLOAN.
WM. SINCLAIR.	JAMES S. M'LENNAN.	EX-PROVOST CLARK.

Hon. Treasurer—JOHN WIGHT, C.A., 150 Hope Street.

Hon. Librarian—JAMES WHITE, 56 Rose Street, Garnethill.

Hon. Secretary and Editor of Transactions—JAMES B. MURDOCH, F.R.Ph.S.E., Capelrig, Mearns.

Assistant Hon. Secretary—GAVIN M. PRATT, 133 West Campbell Street.

Publishing Committee.

JOHN YOUNG.	DUGALD BELL.	GAVIN M. PRATT.
WM. JOLLY.	WILLIAM SINCLAIR.	J. B. MURDOCH, *Convener.*

Library and Museum Committee.

J. SOMMERVILLE.	J. ANDERSON.	J. S. M'LENNAN.
J. RENWICK.	JOHN MAIN.	J. WIGHT, C.A.
JAMES STEEL.	WILLIAM ARMOUR.	JAS. WHITE, *Convener.*

Finance Committee.

DUGALD BELL.	C. L. DOBBIE.
DR. SLOAN.	JOHN WIGHT, *Convener.*

Excursion Committee.

DUGALD BELL.	GAVIN M. PRATT.	JAMES WHITE.
JAMES STEEL.	J. SOMMERVILLE.	J. RENWICK, *Convener.*

Auditors.

DAVID PEARSON.	J. DOUGAN.

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LIST OF MEMBERS, March, 1893.

Year of Election.

Honorary Members.

1865. Geikie, Sir Archibald, LL.D., F.R.S., F.G.S., Director-General of the Geological Survey of Great Britain and Ireland, Museum, Jermyn Street, London, W.

1867. Jones, Professor T. Rupert, F.R.S., F.G.S., 10 Ulverdale Road, King's Road, Chelsea, London, S.W.

1867. Kirkby, James W., Kirkland, Leven, Fifeshire.

1867. Woodward, Henry, LL.D., F.G.S., British Museum, Natural History Department, South Kensington, London, S.W.

1867. M'Chesney, Joseph H., Professor of Geology, University of Chicago, U.S.

1871. Hull, Edward, F.G.S., late Director of the Geological Survey of Ireland, 20 Arundel Gardens, Notting Hill, London, W.

1872. Kelvin, Right Hon. Lord, LL.D., *P.*R.S., Professor of Natural Philosophy, University of Glasgow, *President.*

1872. Young, John, M.D., Professor of Natural History, University of Glasgow.

1879. Hunter, John R. S., LL.D., Daleville, Braidwood, Carluke. [1864]*

1883. Judd, J. W., F.R.S., F.G.S., Science Schools, South Kensington, London, S.W.

1883. Brown, Robert, M.D., F.G.S., Fersley, Rydal Road, Streatham, London, S.W.

1885. Heddle, M. Foster, M.D., F.R.S.E., late Professor of Chemistry and Mineralogy, St. Andrews.

1888. Murray, John, LL.D., F.R.S.E. (of the "Challenger"), 45 Frederick Street, Edinburgh.

1889. Argyll, His Grace the Duke of, Inverary Castle, Inverary.

Honorary Associates.

1867. Struthers, Thomas, 2 Gilmore Terrace Upper, Edinburgh. [1859]

1871. Crosskey, Rev. Henry W., LL.D., F.G.S., 17 Gough Road, Edgbaston, Birmingham. [1858]

* The date *after* a name is that of election as an ordinary member.

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Year of Election.

1871. Horne, James, London. [1858]

1871. Farie, James, Canonbury, London. [1859]

1878. Lapworth, Charles, LL.D., F.G.S., Professor of Geology, Sir Josiah Mason College of Science, Birmingham.

1881. Wünsch, E. A., F.G.S., Carharrack, Scarrier, Cornwall. [1858]

1883. Traquair, R. H., M.D., F.R.S.E., F.G.S., Museum of Science and Art, Edinburgh.

1883. Geikie, James, LL.D., F.R.S.E., F.G.S., Professor of Geology and Mineralogy, University of Edinburgh. [1873]

1886. Robertson, David, F.L.S., F.G.S., Fern Bank, Millport. [1867]

Corresponding Members.

1859. Dougall, Professor John, M.D., 6 Belmar Terrace, Pollokshields, Glasgow.

1860. Sommerville, George, Thornliebank.

1862. Hunter, James, Ironmaster, Coltness.

1864. Mitchell, Rev. Hugh, LL.D., Craig, Montrose.

1865. Winchell, Alex., Professor of Geology, University of Michigan, U.S.

1866. Gloag, Rev. Dr. Paton J., late of the Manse, Galashiels.

1866. Myers, Rev. Edward, F.G.S., 20 Summerhill Terrace, Birmingham.

1867. Craig, Robert, King Cottage, Beith.

1867. Gordon, Rev. Dr., Manse of Birnie, Elgin.

1867. Kerr, David, Markinch, Fifeshire.

1871. Jack, R. L., F.G.S., Government Geologist, Elizabeth Street, Brisbane, Queensland.

1871. Jamieson, T. F., F.G.S., Ellon, Aberdeenshire.

1871. Kinahan, G. H., late of the Geological Survey of Ireland, Dublin.

1871. Ward, John, F.G.S., 23 Stafford Street, Longtown, Staffordshire.

1878. Stewart, Rev. Alex., LL.D., F.S.A.Scot., Ballachulish Manse, Nether-Lochaber.

1883. Lindström, Professor G., State Museum, Stockholm, Sweden.

1883. Scott, Thomas, 14 Lorne Street, Leith Walk, Edinburgh. [1880]

1883. Smith, W. Anderson, Ledaig.

1884. Dobbie, J. J., M.A., D.Sc., Professor of Chemistry and Geology, University College, Bangor, North Wales. [1876]

1884. Nathorst, Dr. Alfred Gabriel, Geological Survey Office, Stockholm, Sweden.

1887. Naismith, Thos., 6 Broompark Terrace, Dennistoun, Glasgow. [1861]

1893. Stewart, Thomas, Yarraville, Australia, c/o James Stewart, Netherby, Stonehaven. [1878]

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Year of Election.

Ordinary and Life Members.

1868. Allan, Archibald B., C.E., Hillock House, Govan Road, Govan.
1882. Anderson, James, 76 West Howard Street, Glasgow.
1881. Armour, William, C.E., 207 West George Street, Glasgow, *Vice-President.*

1875.*Bain, Sir James, 3 Park Terrace, Glasgow.
1867. Bannerman, David, 9 Waterloo Street, Glasgow.
1891. Barnett, James Rennie, Lilybank House, Johnstone.
1858.*Barr, Thomas M., C.E., Caledonian Railway, Perth. [1881]†
1858. Bell, Dugald, F.G.S., 27 Lansdowne Crescent, Glasgow.
1859. Bennie, James, Geological Survey of Scotland, Edinburgh.
1892. Blackwood, Bailie James, Gillsland, Kilmarnock.
1889. Blair, Matthew, 11 Hampton Court Terrace, Garnethill, Glasgow.
1887. Boyd, John, 9 Prince's Square, Regent Park, Glasgow.
1882. Brand, John, 81 Gloucester Street, Glasgow.
1887. Brown, Andrew, 27 Roselea Drive, Dennistoun, Glasgow.
1883. Brown, George S., B.Sc., 19 Windsor Street, Glasgow.
1892. Brown, John Arthur, Dowanhill Gardens, Glasgow.
1890. Brownlie, Robert, 8 Ardgowan Terrace, Sandyford, Glasgow.
1892.*Buchan, W. P., Fairyknowe, Cambuslang.
1877. Buchanan, John, 230 Duke Street, Glasgow.
1888. Burnet, J. M., Duncairn Villa, Crosshill, Glasgow.
1866. Burnet, John, 167 St. Vincent Street, Glasgow.

1892. Caldwell, Hugh, The Braes, Bridge of Weir.
1873. Cameron, Robert, Wellpark House, Bathgate.
1877. Campbell, John MacNaught, Kelvingrove Museum, Glasgow.
1880. Carmichael, Robert S., Audit Office, St. Enoch Station, Glasgow.
1891. Carson, John, 6 Doune Quadrant, Kelvinside, Glasgow.
1890. Chalmers, John, 15 Iona Place, Mount Florida, Glasgow.
1892. Cherry, James S., Trefoil Avenue, Shawlands, Glasgow.
1888. Clark, Ex-Provost, Chapel House, Paisley.
1875.*Clavering, Thomas, 27 St. Vincent Place, Glasgow.
1883. Cleland, John, B.Sc., C.E., Woodhead Cottage, Old Monkland.
1875.*Collins, Sir William, 3 Park Terrace, East, Glasgow.
1866. Connal, Sir Michael, Virginia Buildings, Glasgow.
1891. Cowie, Charles, Woodend, Partick.
1874, Cox, C. C., Castle Street, Barnstaple.

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1877.*Dansken, John, 121 West Regent Street, Glasgow.
1874. Darling, George E., 178 St. Vincent Street, Glasgow.
1881. Dickson, John, 196 Parliamentary Road, Glasgow.
1883.*Dobbie, Charles Lizars, 21 St. James Street, Hillhead, Glasgow.
1886. Dobbie, Rev. R. W., 17 Broompark Drive, Dennistoun, Glasgow.
1881.*Dougan, John, 13 Leven Street, Pollokshields, Glasgow.
1889. Douglas, William, Golconda, Kilwinning.
1888. Dow, Walter, Bekeni, Dalziel Drive, Pollokshields, Glasgow.
1887. Dow, Wm., 165 Hospital Street, Glasgow.
1867. Drew, Alexander, 15 Nicholas Street, Manchester.
1883. Dunlop, Robert, Whiterigg, Airdrie.
1868. Dunn, William, 183 West George Street, Glasgow.

1884. Edmiston, James, 297 Argyle Street, Glasgow.

1872.*Farquhar, Ex-Bailie John, 13 Belhaven Terrace, Hillhead, Glasgow.
1872. Forsyth, David, M.A., D.Sc., Higher Grade School, Leeds.

1866. Gale, James M., C.E., Corporation Water Works, Glasgow.
1892. Gardner, Alexander, 192 Hope Street, Glasgow.
1887. Gardner, John, 21 Clyde Place, Glasgow.
1884. Gill, Robert, 109 West George Street, Glasgow.
1873.*Gilmour, Thomas, M.D., Port Ellen, Islay. [1878]
1879. Graham, Alex. M., 20 Dixon Street, Glasgow.
1888. Graham, James D., M.A., Ayr Grammar School, Ayr.
1877. Graham, M. M., 21 Bath Street, Glasgow.
1866. Grant, James, 8 Queen's Terrace, Glasgow.
1881. Gray, Harry, 15 Newton Terrace, Glasgow.
1886. Guy, Robert, 120 West Regent Street, Glasgow.

1890. Hair, Wm. B., 5 Mansfield Place, West Regent Street, Glasgow.
1872. Hamilton, Archibald, C.E., Clyde Navigation Office, Robertson Street, Glasgow.
1880. Harvie, John, Clydesdale Bank, 30 St. Vincent Place, Glasgow.
1885. Henderson, George G., M.A., Andersonian Buildings, 204 George Street, Glasgow.
1880. Henderson, James, M.A., Whitehill School, Dennistoun, Glasgow.
1876. Henderson, John, 8 Cecil Place, Paisley Road, Glasgow.
1893. Hogg, R. M., Teacher, Irvine.
1886. Hewett, H. S., 8 Milton Terrace, Langside.
1877. Hill, Thomas N., 140 Bath Street, Glasgow.

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1877. Hislop, George R., F.C.S., F.R.S.S.E., Corporation Gas Works, Paisley.
1891. Hodge, William, 27 Montgomerie Drive, Kelvinside, Glasgow.
1892. Hodge, Wm., Craigvinean, Nithsdale Drive, Pollokshields, Glasgow.
1870. Horne, R. R., Mount Vernon Colliery, Tollcross.
1884. Howat, John, 527 New City Road, Glasgow.
1866. Hunt, Edmund, C.E., 87 St. Vincent Street, Glasgow.

1890. Johnstone, Ronald H., 75 West Nile Street, Glasgow.
1884. Jolly, William, F.R.S.E., F.G.S., Greenhead House, Govan, *Vice-President.*

1870.*Ker, William, 1 High Windsor Terrace, Glasgow.
1877. Kerr, Charles James, Greenfaulds House, Cumbernauld.
1890. Kidston, Robert, F.G.S., 24 Victoria Place, Stirling.
1877. Kincaid, Thomas, 9 Lansdowne Crescent, Glasgow.
1882. King, Hugh B., Kilwinning, Ayrshire.
1882. King, Robert C., C.A., Kilwinning, Ayrshire.
1874. King, Thomas, 110 Hill Street, Garnethill, Glasgow.
1860. Kirsop, John, 98 Argyle Street, Glasgow.
1867. Knox, Adam, 10 Clayton Terrace, Dennistoun, Glasgow.
1872. Knox, John, 58 Bath Street, Glasgow.

1892. Laird, Alexander, 63 Wilson Street, Glasgow.
1883. Laird, Andrew, C.E., 123 St. Vincent Street, Glasgow.

1874.*Lamb, Thomas, 190 Parliamentary Road, Glasgow.
1880. Lucas, William, 133 West George Street, Glasgow.
1892. Lusk, Hugh D., Rosebank, Forsyth Street, Greenock.

1866. M'Clelland, Andrew S., C.A., 115 St. Vincent Street, Glasgow.
1889. M'Creath, George W., M.E., 208 St. Vincent Street, Glasgow.
1884. M'Donald, A. B., C.E., 64 Cochrane Street, Glasgow.
1890. M'Ewan, William, 148 Bothwell Street, Glasgow.
1892. M'Farlane, John R., 22 Royal Exchange Square, Glasgow.
1867. M'Glashan, John, 114 Candleriggs, Glasgow.
1882. Mackintosh, Rev. John, The Manse, Uddingston.
1888. M'Intosh, Very Rev. Canon, Airdrie.
1888. Macintyre, Duncan, North Public School, Alexandria.
1886. M'Laren, Robert, Bonny, Gardenside, Uddingston.
1881.*Maclay, David J., 3 Woodlands Terrace, Glasgow.
1877. M'Lay, William, 11 May Terrace, Mount Florida, Glasgow.

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1882. M'Lennan, James S., Oswald Public School, Knightswood, Maryhill.

1883. M'Whirr, John, 10 Kilmailing Terrace, Cathcart.

1887. Main, John, F.G.S., 21 Hartington Gardens, Dowanhill, Glasgow.

1874. Marshall, Robert, 97 Wellington Street, Glasgow.

1887. Meiklejohn, Andrew, 3 Windsor Street, Glasgow.

1867. Millar, John (J. Black, Drew, & Co.), 23 Royal Exchange Square, Glasgow.

1877. Millar, W. J., C.E., 261 West George Street, Glasgow.

1892. Miller, William, 1 Stanmore Terrace, Mount Florida, Glasgow.

1881. Mitchell, G. A., 67 West Nile Street, Glasgow.

1887. Mitchell, Robert, 24 Howard Street, Bridgeton, Glasgow.

1885. More, Robert, 505 Sauchiehall Street, Glasgow.

1877. Moore, Robert T., C.E., B.Sc., 158 St. Vincent Street, Glasgow.

1889. Motherwell, A. B., British Linen Bank, Airdrie.

1859. Murdoch, James B., F.R.Ph.S.E., Capelrig, Mearns, Renfrewshire, *Honorary Secretary.*

1875. Murdoch, William, 11 Bothwell Street, Glasgow.

1870.*Murray, David, LL.D., 169 West George Street, Glasgow.

1865. Napier, J. W., Woodielea, 14 Windsor Circus, Glasgow.

1891. Neilson, James, High Crosshill, Rutherglen.

1868. Neilson, Richard, 33 Virginia Street, Glasgow.

1867. Norman, John, 131 St. Vincent Street, Glasgow.

1869. Orr, John, 12 Newhall Terrace, Glasgow.

1890. Parker, T. Carter, Clare House, Huddersfield.

1889. Parker, Wm. Ernest, Middle Class School, Barnstaple.

1875. Pearson, D., 15 Carnarvon Street, Glasgow.

1891. Pollock, Arthur, Kirkland, Bonhill, Dumbartonshire.

1877. Pratt, Gavin M., 104 West Graham Street, Glasgow, *Assistant Hon. Secretary.*

1873. Rankine, David, C.E., 75 West Nile Street, Glasgow.

1880. Reid, James A. (of M'Grigor, Donald, & Co.), 172 St. Vincent Street, Glasgow.

1890. Reid, James B., c/o Mrs. Gillanders, 449 St. Vincent Street, Glasgow.

1874. Renwick, John, Blacklands, Maryhill.

1877. Rhind, John, 82 Hill Street, Garnethill, Glasgow.

1887. Richmond, Thomas, L.R.C.P.E., 2 West Garden Street, Burnbank, Glasgow.

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1872. Robertson, David, 205 Hope Street, Glasgow.
1866. Robertson, John, 10 Valeview Terrace, Mount Florida, Glasgow.
1868. Robertson, Joseph, 110 John Street, Glasgow.
1878. Ross, David, LL.D., 47 Carnarvon Street, Glasgow.
1875.*Rottenburg, Paul, Holmhurst, Dowanhill Gardens, Glasgow.
1865. Rowan, David, 22 Woodside Place, Glasgow.

1889. Scott, John, 3 M'Aslin Street, Glasgow.
1891.*Sharp, John Grant, 127 Great Hamilton Street, Glasgow.
1889. Simpson, Rev. Alex., B.A., B.Sc., F.G.S., 46 Prince's Square, Strathbungo, Glasgow.
1888. Sinclair, Thomas, 206 New Dalmarnock Road, Glasgow.
1887. Sinclair, William, Grange, Bothwell.
1889. Sloan, Dr. Samuel, 5 Somerset Place, Sauchiehall Street, Glasgow.
1871.*Smellie, Thos. D., 213 St. Vincent Street, Glasgow.
1865. Smith, John, Monkredding, Kilwinning, Ayrshire, *Vice-President.*
1891. Smith, J. Parker, M.P., Jordanhill, Partick.
1887. Somerville, Rev. James E., B.D., 11 Southpark Terrace, Hillhead, Glasgow.
1871. Sommerville, Joseph, 5 Huntly Terrace, Kelvinside, Glasgow.
1881. Steel, James, 14 Shamrock Street, Glasgow.
1884. Steele, Robert Innes, 28 Leven Street, Pollokshields, Glasgow.
1893. Steele, Wm., 12 Wendover Crescent, Mount Florida, Glasgow.
1880. Stewart, James, of Williamwood, Cathcart.
1891. Starke, Robert, 43 West Regent Street, Glasgow.
1891. Stirling, David, 49 Jamaica Street, Glasgow.

1858. Thomson, James, F.G.S., 26 Leven Street, Pollokshields, Glasgow.
1885. Tullis, David, Glencairn, Burnside, Rutherglen.
1885. Tullis, James T., The Anchorage, Burnside, Rutherglen.

1874. White, James, 56 Rose Street, Garnethill, Glasgow, *Hon. Librarian.*
1874. White, James, Free Normal School, Glasgow.
1880. Whitelaw, Thomas, Coalmaster, Motherwell.
1874. Whyte, John, 150 Holland Street, Glasgow.
1866. Wight, John, C.A., 150 Hope Street, Glasgow, *Hon. Treasurer.*
1879. Wight, Robert John, C.E., Hampton Villa, Aytoun Road, Pollokshields, Glasgow.
1881. Wotherspoon, David, 130 Dumbarton Road, Glasgow.

1859.*Young, John, LL.D., F.G.S., Hunterian Museum, University of Glasgow. [1869]

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